Long-Term Assessments Of Some Vessel-Source Marine Pollutants

by

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ABSTRACT

Accidental and deliberate discharges from maritime transportation activities have been widely perceived as major sources of pollution. Preventive and control management strategies have therefore been progressively introduced internationally to reduce and eliminate these inputs to the marine environment. The long-term effectiveness of these measures, applied to vessels operating in the waters around the British Isles, is the research question that has been under investigation by the author since 1971.

Following analyses of stakeholders' interests and concerns, and associated information requirements, the aims and objectives of a phased work programme were identified. These focused primarily upon three vessel-source marine pollutants; oil or oily mixtures, packaged dangerous or harmful goods and garbage.

After a review of the literature, assessment strategies, designs, methodologies and analytical techniques were devised and applied over varying spatial and temporal scales. A data acquisition and management system, utilising questionnaire returns from 13 reporting organisations, was employed to support an annual survey on marine oil pollution. A similar approach, combined with published information, facilitated a characterisation of packaged chemical incidents around the coastline and changes over time.

To determine different sources and other attributes of marine litter, an ocean-focused beach survey design was devised and applied on the shores of the English Channel, Irish Sea, North-East Atlantic Ocean and North Sea. A series of surface drift experiments and an open-water sighting survey provided further information on movements and densities of marine litter in the open sea.

Research outputs, including the publications submitted, have been reviewed and identified as authoritative sources of information by the competent authorities and other interested parties. These include the Department of the Environment, Transport and the Regions, European Commission, International Maritime Organisation, Royal Commission on Environmental Pollution, Smithsonian Institution for Short-Lived Phenomena and the United States National Oceanic and Atmospheric Administration.

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ACRONYMS AND ABBREVIATIONS

ACOPS:	Advisory Committee on Protection of the Sea.
CEC:	Commission of the European Communities.
CERES:	Coalition for Environmentally Responsible Economies.
CIA:	Chemical Industries' Association.
DDPH:	Dissolved/dispersed petroleum hydrocarbons.
DoE:	Department of the Environment (Department of the Environment, Transport and the Regions from 16 June 1997).
DTp:	Department of Transport (Department of the Environment, Transport and the Regions from 16 June 1997).
DTI:	Department of Trade and Industry.
FSA:	Formal Safety Assessments.
GESAMP:	Joint Group of Experts on the Scientific Aspects of Marine Pollution (of the UN).
HDPE:	High density polyethylene.
HMCG:	Her Majesty's Coastguard.
HNS Convention:	International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances (HNS) by Sea.
ICS:	International Chamber of Shipping.
IGOSS:	Integrated Global Ocean System.
IMDG Code:	International Maritime Dangerous Goods Code.
IMO:	International Maritime Organisation.
IOC:	Intergovernmental Oceanographic Commission (of UNESCO).
ISM Code:	International Management Code for the Safe Operation of Ships and for Pollution Prevention.
ISU:	International Salvage Union.
ITOPF:	International Tanker Owners' Pollution Federation Ltd.
MARPOL 73/78:	International Convention for the Prevention of Pollution from Ships 1973, as modified by the 1978 Protocol thereof.

MEPC:	Marine Environment Protection Committee (of the IMO).
MLRP:	Marine Litter Research Programme
MSA:	Marine Safety Agency
NGOs:	Non-Governmental Organisations
OCIMF:	Oil Companies International Marine Forum.
OILPOL:	International Convention for the Prevention of Pollution by Oil.
PET:	Polythene terephthalate.
PPM:	Parts per million
PRTR:	Pollutant Release and Transfer Register.
PVC:	Polyvinylchloride.
RCEP:	Royal Commission on Environmental Pollution.
Ro-ro:	Roll-on roll-off vessel.
SOLAS:	International Convention for the Safety of Life at Sea.
TBG:	The Tidy Britain Group.
THC:	Total hydrocarbon concentration.
UKCS:	United Kingdom Continental Shelf.
UNCED:	United Nations Conference on Environment and Development.
WWF:	World Wide Fund for Nature.

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Technical networks have been established over the years with hundreds of corporate organisations, trade associations, government departments and inter-governmental organisations on a global scale. Invaluable contributions have been received from the British Plastics Federation, Chemical Industries' Association, Department of the Environment, Transport and the Regions, International Maritime Organisation, ITW Hi-Cone and Ministry of Defence to name just a few.

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1.0 ENVIRONMENTAL AND SAFETY CONCERNS

The state of the marine environment as regards pollution has become an increasingly important issue of concern to the scientific community, national and international policy makers and the general public. In response, an increasing number of frameworks have been developed at governmental and inter-governmental levels to address these problems through improved preventive and control management strategies. For example, Chapter 17 of Agenda 21 of the United Nations Conference on Environment and Development (UNCED) called for management-related activities to prevent, reduce and control degradation of the marine environment from land-based and sea-based activities, including shipping (UNCED, 1992). Our current state of knowledge has shown that shipping operations are sources of a wide range of inputs to both the marine and atmospheric environments. Discharges and emissions include oil, chemical cargoes, garbage, anti-fouling paints, sulphur and nitrogen oxides (Pullen, 1996).

Historically, public opinion has identified vessel-source pollution as a major threat to the marine environment. Oil at sea and litter were environmental issues raised more than once in oral or written evidence to the Royal Commission on Environmental Pollution (RCEP) in 1982 (RCEP, 1984). A 1984 EEC-wide survey examining public attitudes to the environment discovered that most respondents regarded the threat to sealife and beaches from oil spills as the most worrying problem facing Europe (Anon., 1984). Similar perceptions were evident from the results of three surveys commissioned by the Department of the Environment (DoE) during 1986,1989 and 1993 (DoE, 1994).

Having considered the concept of quality management and its application to shipping operations, Rawson (1995, p. 62) noted that "the public see the industry as either part of, or apologists for, the worst operators: the bulk carriers that fall apart, the tankers that pollute and the dirty, rusty tween deckers." Partly in response to public opinion, some governments have given priority to the reduction and elimination of the more obvious forms of vessel-source marine pollution since the 1920's. Particular attention was directed

to oil, followed by other noxious and hazardous substances and garbage (Anon., 1971; Portmann, 1977; Nauke & Holland, 1992).

Following the grounding of the tanker *Braer* in January 1993, a wide ranging inquiry was undertaken by Lord Donaldson for HM Government to advise on whether any further measures were appropriate and feasible to protect the UK coastline from pollution from merchant shipping. The Inquiry's Report contained 103 recommendations including those concerning operational as well as accidental vessel-source marine pollution (Anon., 1994). In January 1996 the Government announced a package of 18 measures to reduce the dumping of waste at sea by all types of vessels. These are intended to improve provision and use of port reception facilities, tighten regulations on legal discharges by ships and improve enforcement of waste regulations (DTp, 1996). The Merchant Shipping and Maritime Security Act 1997 contains appropriate enabling powers.

1.1 Oil

Although it is now recognised that there are many sources of input of petroleum to the sea, there is little argument that the main source of oil in bulk quantity is from shipping. Vessel-source marine oil pollution is generally attributed to two types of discharges, operational and accidental. Ehler & Basta (1983) defined operational discharges as those occurring routinely and internationally as a result of normal operating procedures; accidental discharges were subdivided into operational spills involving relatively small amounts of oil, typically resulting from equipment malfunctions on board vessels, and casualty-spills involving vessel casualties following groundings, collisions, explosions and similar causes.

The significance of operational discharges was not fully apparent on a regional or global scale until the 1960's and 1970's, following major developments in the seaborne trade in crude oil and oil products. Routine discharges of oily wastes from tanker deballasting and tank cleaning operations accounted for the largest quantities of oil entering the sea from marine transportation activities. These inputs were estimated at 1.35 million tonnes yr^{-1} in

1971 (National Academy of Sciences, 1975a). Corresponding global estimates for 1989 showed a marked decline in oil discharges from all shipping operations (Marine Environment Protection Committee, 1990). However, the United Nations Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) has drawn attention to a worldwide shortage of adequate port reception facilities for proper disposal of fuel oil sludges and machinery space bilge waters (GESAMP, 1990).

The effects of chronic oil pollution in the marine environment have been the subject of numerous studies over the years. Most popular concern has been directed toward seabird mortalities (Bourne, 1969) and the consequences of chronic pollution of beaches on a large geographical scale. Results from beached bird surveys carried out for many years on north-west European shores have indicated substantial seabird mortalities from chronic oil pollution, largely attributed to illegal operational discharges from ships (Bourne & Bibby, 1975; Andrews & Standring, 1979; Stowe, 1982; Stowe & Underwood, 1984; Dahlmann *et al.*, 1994).

Widespread distributions of tar residues have been reported in coastal and oceanic waters in many parts of the world since the 1960's. Analyses of chemical characteristics of pelagic tar samples have shown crude oil sludge discharges from tankers to have been a major source. Persistence has been measured in residence times ranging from a few months to two years in the oceans (Butler *et al.*, 1973; Levy & Walton, 1976), with similar time intervals on beaches (Brunnock *et al.*, 1968; Knap *et al.*, 1980). Reports of the adverse effects of chronic oil pollution of shorelines have often referred to damage to the local tourist industry. Atwood *et al.*, (1987) noted in the Wider Caribbean region that when beach tar values reached 10 g m^{-1} (shoreline frontage) visitors became soiled by tar, and when values approached 100 g m^{-1}, beaches became virtually unusable for tourist purposes.

Some large scale studies have indicated that beach tar levels have decreased over the last two decades in the mid-North Atlantic, eastern Mediterranean and east Asian regions. For example, Golik *et al.*, (1988) published statistics showing significant reductions in the amounts of floating tar observed in the Mediterranean Sea between 1969 and 1987. Their findings were partly attributed to marked changes in the patterns and volumes of

movements of oil by sea, but also to the introduction and effective implementation of control and prevention measures. The relevant international instruments, their major requirements and other details are given in Table A1.1.

Human error has been identified as the primary cause of most maritime accidents (Anon., 1994). Devanney & Stewart (1974) established, from world wide data on tanker spills, that the number of accidents was broadly proportional to the volume of oil handled, and they produced probabilities and recurrence intervals for different numbers of spills per year and different spill sizes. Most tanker-casualty spills occur within 80 km of the coastline, particularly in narrow straits and entrances to ports and harbours. Statistics compiled by the International Tanker Owners Pollution Federation (ITOPF) show reported causes of oil spills from tankers, combined carriers and barges since 1974 (Table 1.1). Most incidents occurred during routine operations in ports or at oil terminals, although collisions, groundings and other accidents caused the majority of spills over 700 tonnes (International Tanker Owners Pollution Federation, 1997).

	< 7 tonnes	7-700 tonnes	> 700 tonnes	Total
OPERATIONS				
Loading/discharging	2753	275	15	3043
Bunkering	541	24	0	565
Other operations	1145	45	0	1190
ACCIDENTS				
Collisions	143	221	83	447
Groundings	216	179	95	490
Hull failures	541	68	36	645
Fires & explosions	147	14	20	181
OTHER	2227	158	36	2421
TOTAL	**7713**	**984**	**285**	**8982**

Table 1.1 Reported causes of oil spills from tankers, combined carriers and barges, 1974-1996. (From: International Tanker Owners Pollution Federation, 1997).

Only a small proportion of tanker-casualty spills have caused massive oil pollution; for example, approximately 13% of accidental spills recorded by ITOPF were > 700 tonnes (Table 1.1). Surveys carried out by the International Salvage Union (ISU) between 1994 and 1996 concluded that 4.974 million tonnes of crude oil cargoes had been recovered by their members, thereby preventing major spills (Anon.,1997). The consequences of massive oil pollution are well documented in the literature. Severe damage has occurred at local levels with time-curves of recovery lasting up to a decade later (Clark, 1986). The major costs of massive oil spills include expenditure on clean-up operations, income lost because of adverse effects upon commercial fisheries, the value of lost recreation opportunities, income lost by the tourist industry and the value of the spilled oil and lost tanker (Anon., 1983). Wardley-Smith (1973) suggested that a further major impact of such events is upon local and world public opinion, leading to ill-informed judgements concerning the problem of oil pollution.

Maritime accidents have been reduced through improved safety standards, better navigational aids, more intensive training of seafarers and new regulatory developments pertaining to the management of shipping traffic in the open sea (GESAMP, 1990). In addition, the International Maritime Organisation (IMO) has adopted many instruments in order to ensure adequate and timely response to accidents as well as to provide schemes for compensation, manuals on combating pollution and contingency planning (IMO,1997a). The annual numbers of oil spills over 700 tonnes from tankers, combined carriers and barges have declined markedly between 1970 and 1996 (Figure 1.1). Similarly, Lloyds Register of Shipping's casualty reports identified a casualty rate of 2.36 per hundred tankers between 1973 and 1979 compared with a corresponding value of 1.95 for the period 1980 to 1987 (Steering Group on Casualty Statistics, 1988). However, an additional factor from which greater risks emanate is the increasing age of the world's tanker fleet.

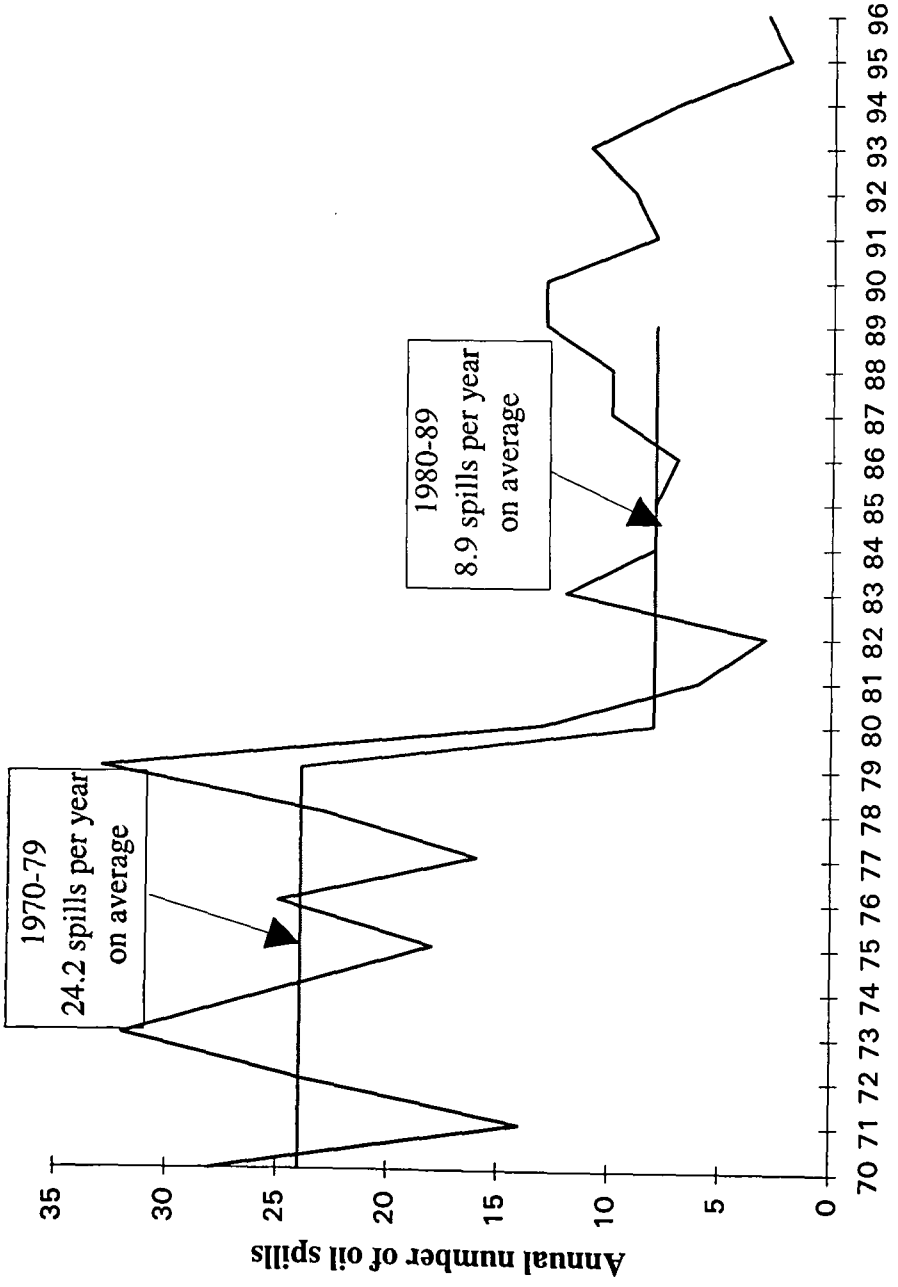


Figure 1.1: Annual numbers of oil spills over 700 tonnes from tankers, combined carriers and barges, 1970-1996. (From: International Tanker Owners Pollution Federation, 1997)

1.2 Packaged dangerous/harmful goods

The IMO have developed classification criteria in the International Maritime Dangerous Goods (IMDG) Code which identify dangerous goods and harmful substances carried by sea in packaged form (Table 1.2). Dangerous goods are those noxious and hazardous substances, or groups of substances, which may jeopardize the safety of ships or their crews including compressed gases, corrosives, oxidising agents, flammable and poisonous substances, explosives and radioactive materials. Harmful substances are those which have bioaccumulative, highly toxic or tainting properties, and therefore pose a risk to living resources in the form of marine pollutants. Approximately 600 polluting substances were identified by GESAMP in the 25th amendment of the IMDG Code (IMO, 1990). In practice, most marine pollutants are also dangerous goods, and it is a general principle that safety considerations take priority over environmental concerns.

Hazardous or polluting substances other than oil can be transported by sea in three different modes: in dry-bulk cargo carriers; in liquid bulk or parcel tankers, or by container vessels and general cargo ships. Several hundreds of chemicals are shipped in bulk form while another several thousands of different chemicals are shipped in packaged form in containerised or non-containerised shipments. Few statistics are available concerning Britain's seaborne trade of packaged dangerous/harmful goods. The most recent showed that during 1989 approximately 3.6 million tonnes passed through ports. Of these, 1 million tonnes was carried in ro-ro ships and the remainder in container and general cargo ships (K. James *pers. comm.*).

As a consequence of heavy weather damage or following vessel-casualties a wide range of different dangerous/harmful cargoes in packaged form have been lost at sea. In the waters around the British Isles examples include IMDG Code Class 6.1 poisonous (toxic) substances and marine pollutants dinoseb, lindane (gamma-HCH), *ortho*-cresol, potassium cyanide and sodium cyanide, Class 3.3. flammable liquid and marine pollutant, styrene and Class 6.1. poisonous (toxic) substance, toluene di-isocyanate (Anon., 1972b; Dixon, 1981; Koops, 1988; Anon., 1990a). The quantities of lost chemicals recovered has been partly dependent upon the types and capacities of primary and transport packagings, which have

ranged from a few grammes in individual sachets to quantities of 20 tonnes or more in tank containers. The contents of some of these packages have leaked into the sea and depending upon the amounts, behaviour, chemical, physical and ecotoxological properties, have threatened marine life or public safety over different areas and time intervals.

Class	Nature of Hazard[a]
1	Explosives.
2	Gases: compressed, liquefied or dissolved under pressure.
3	Flammable liquids.
4.1	Flammable solids.
4.2	Substances liable to spontaneous combustion.
4.3	Substances, which in contact with water, emit flammable gases.
5.1	Oxidising substances
5.2	Organic peroxides
6.1	Poisonous (toxic) substances.
6.2	Infectious substances
7	Radioactive materials
8	Corrosives.
9	Miscellaneous dangerous substances (any other substances which experience has shown, or may show, to be of a dangerous character).

[a] Each substance defined as harmful is identified as a "Marine Pollutant" in its individual schedule of the Code

Table 1.2: Classification of dangerous goods by human hazard in the International Maritime Dangerous Goods (IMDG) Code. (From: IMO, 1994).

Law (1994) identified a theoretical maximum area of 100 km square which could be affected by a 10 tonne release of an organophosphorus insecticide in the English Channel. Furthermore, it was noted that every incident involving the release of toxic chemicals to the marine environment causes some harm, including the disruption of fishing activity, a loss of confidence of customers in the wholesomeness of fish and shellfish, costs to government of control, recovery and monitoring, and costs incurred by the competent authorities in identifying, monitoring and cleaning-up materials washed up on beaches. The non-financial costs identified included damage to marine species which are not commercially exploited, and reduction in amenity use of any impacted areas. The total Danish financial costs incurred in connection with the 1984 search and recovery operation for 53 of the 80 Dinoseb drums lost from the *Dana Optima* in the North Sea amounted to approximately US$ 1.9 million, and nearly all drums were found in a leaking condition (Stamp, 1988).

A widespread recognition of safety and environmental risks posed by incidents involving packaged dangerous/harmful goods has led to progressively stricter enforcement of the various regulations and codes covering the marking, labelling, proper packaging and stowage of these materials (Table A1.1).

1.3 Ships' garbage

During the early 1970's it was estimated that the flux of litter to the world's oceans amounted to 6.4 million t yr^{-1} (National Academy of Sciences, 1975b). By the end of the 1980's plastics litter was identified as a possible new addition to the primary list of marine pollutants, and one of six areas of immediate concern for the marine environment on a global scale (GESAMP, 1990; McIntyre, 1992). More recently, all types of litter have been classified as one of the major categories of contaminants from land-based sources which are considered to have real or perceived effects upon the coastal marine environment on a global scale (UNCED, 1991; Windom, 1992). Substantial increases in the quantities of these wastes entering the marine environment have therefore occurred during the last two decades. The proceedings of 4 international symposia refer to the extensive literature

on all aspects of the global marine litter problem (Shomura & Yoshida, 1985; Wolfe, 1987; Shomura & Godfrey, 1990; Clary, 1995; Faris & Hart, 1995).

Major sources of these wastes have been traced to discharges of ships' garbage at sea, materials carried to the sea by rivers and municipal drainage systems and litter left behind by beach users (Pruter, 1987). Typical items include derelict fishing gear, plastic bags or sheeting, strapping bands, rope, wire, clothing and light bulbs. Greatest concentrations of marine litter have been recorded along coastal margins because 80% of merchant marine activities are generally nearshore (National Academy of Sciences, 1975b). Attention has also been drawn to the high densities of marine litter at mouths of major estuaries and at convergent frontal systems (Pruter, 1987; Vauk & Schrey, 1987). An early 1980's onboard observational study concluded that 6.8 million metal, 0.4 million glass and 0.6 million plastics containers were disposed of daily from merchant ships at sea around the world (Horsman, 1982).

A growing body of evidence has suggested that all types of marine litter in general, and plastics in particular, pose significant threats to marine mammals, seabirds, amphibians, fish and crustaceans (Laist, 1987). Plastics materials have been singled out for special treatment because of their perceived hazard levels in the marine environment (Goldberg, 1995). They include their geometric features and related physical entanglement potential, suspected extended lifetimes and therefore prolonged duration of entanglement hazard, physical properties concerning specific gravity and strength, and toxicity, if ingested, from compounding ingredients used in the fabrication process (Andrady, 1988).

In addition to impacts on wildlife, there is a widespread general belief that floating litter accumulates over long time intervals, where it degrades marine habitats and interferes with recreational amenities. On North Sea beaches in Germany, up to 20% of bathers have complained about injuries caused by items of litter (Standing Advisory Committee for Scientific Advice, 1986).

2.0 PRIMARY AIMS OF THE RESEARCH AND OVERVIEW STRUCTURE

Following consideration of potential environmental and safety concerns attributed to operational and accidental discharges from shipping, primary aims of the research are identified. Relationships between the set of publications submitted, primary aims of the research and overview structure are then examined. Finally, relevant data quality considerations are identified and discussed.

2.1 Primary aims of the research

The primary aims of the research, which is ongoing, are to:

(i) Devise and apply assessment strategies, methodologies and analytical techniques for some vessel-source discharges to coastal and oceanic waters.

(ii) Design and carry out temporal trend assessments relating the quantities, sources and types of pollution to relevant regulatory standards.

2.2 Relationship between the set of papers submitted and structure of the overview

Over a period of more than 25 years the author has studied, and contributed to, developments in assessment methods for vessel-source marine pollution. A set of 40 publications submitted outlines these contributions concerning operational and accidental discharges of oil or oily mixtures, packaged dangerous or harmful goods and garbage. The structure of the overview summarises these developments and analyses the validity and contexts of the contributions. For each of the specified pollutants therefore, a research

question is defined, a work programme and method of approach outlined, principal findings summarised and current, related or future research work identified.

The marine oil pollution publications show how the author acquired background knowledge during the 1970's that identified and measured major attributes of operational and accidental discharges from shipping (for example, Dixon & Dixon, 1972; 1975; 1976). The knowledge was later applied to design data collection and management systems in the United Kingdom and elsewhere in Europe (for example, Dixon, 1985). Remaining publications identify principal findings from a representative sample of annual oil pollution surveys completed since 1978 (for example, Dixon & Dixon, 1985; 1987; 1996). The findings have since been applied by different stakeholder groups, and currently by the author, in long-term evaluations of pollution prevention and control activities (for example, Marine Environment Protection Committee, 1996; Dixon, 1997).

A similar process was followed in assessments of incidents involving packaged dangerous and harmful goods. The selected publications identify environmental and safety concerns and outline methods applied to collect relevant data (for example, Dixon & Dixon, 1981a; 1986). Long-term effectiveness of regulatory and other controls was then determined following comparisons of appropriate data sets (for example, Dixon, 1992). Separate assessments were undertaken to more fully understand sources and types of explosives ordnance and other hazardous materials recovered on beaches and in nearshore waters (for example, Dixon & Dixon, 1979).

Publications on marine litter outline assessment studies completed on beaches and in the open sea. These include initial characterisation of environmental and safety concerns (for example, Dixon & Dixon, 1981b), development of methodologies and analytical techniques (for example, Dixon & Dixon, 1983a), identification of spatial and temporal trends (for example, Dixon & Dixon, 1983b) and finally evaluations of the effectiveness of regulatory and other controls (for example, Dixon, 1995).

2.3 Relationship between the structure of the overview and primary aims of the research

The following chapters of this overview trace developments through different stages of the research demonstrating how primary aims were achieved. In section 3 stakeholder interests and concerns are identified with particular reference to information required to assess the effectiveness of preventive and control measures. Section 4 reviews different sources and types of marine oil pollution data, and then explains how an appropriate data collection and management system was developed and applied to integrate available information within a single reporting system. To demonstrate applications some short-term temporal trends are identified from statistics compiled between 1993 and 1995. Background details are also given for a current study identifying and analysing long-term trends from the data.

Data sources and assessment methods for major and minor incidents following losses of packaged dangerous or harmful goods at sea are outlined in section 5. Analysis of recurring problems experienced by local authorities during search, recovery and related operations provided a primary means of determining the effectiveness of preventive and precautionary measures. These included, for example, IMDG Code requirements concerning marking and labelling of packages.

In section 6 major factors considered in the design and application of assessment studies to measure vessel-source marine litter are identified and discussed. These included assessment strategy types, field sampling designs, measurement scales and analytical techniques. From various aggregations of data statistically verifiable hypotheses were constructed to identify any significant long-term differences between observed compositional elements and quantities of marine litter. Comparisons between paired data sets for two Scottish study areas, for example, indicated that the MARPOL 73/78 Annex V regulations were not being observed by vessels operating in the waters adjacent to both study areas.

Broad conclusions drawn from the research are presented in section 7. These include major developments in assessment methodologies, how effective these have been and what impact they have had on policies and actual pollution.

2.4 Data quality

From the beginning of the research it was evident that the success of the various programmes or studies was dependent upon the reliability of assessments and interpretation of data. In assessments of temporal trends, for example, it was necessary to understand the degree to which data generated over the years was directly comparable. Although formal Quality Assurance or Quality Control systems did not exist during the 1970's, the author applied appropriate practices and procedures in collection and analysis of data. Their aims were to provide acceptable levels of assurance for meaningful assessments to be completed in accordance with the objectives of each study.

Practices and procedures employed were described in key publications and details have been summarised in appropriate parts of the overview. During questionnaire surveys causes of non-response were examined and any gaps in geographical coverage identified (for example, Dixon, 1992). Key sources of error were identified and quantified whenever possible (for example, Dixon & Dixon, 1983). Reference materials and other information were obtained from product and packaging manufacturers to assist identification of packagings and other materials in the field (for example, Dixon & Dixon, 1985).

Information provided by competent authorities was generally considered to be the best available. To identify any major shortcomings and allow corrective actions to be taken, reports were often cross-referenced with other sources of information for the same incidents or events. In North Sea Oilfields accidental pollution reports submitted by offshore operators were compared with those returned by other independent sources including local authorities and environmental groups (for example, Dixon & Dixon, 1996).

In general, therefore, it was believed that adequate steps had been taken to ensure that data was of sufficient quality to fulfil the objectives of each study. However, further improvements can still be made in determining the acceptability of data such as the development of more objective criteria.

3.0 MANAGEMENT INFORMATION NEEDS

The primary aim of this section is to examine management information needs for major stakeholder groups concerned about vessel-source marine pollution. In the design of assessment studies, management information needs were carefully evaluated to ensure that objectives and measured parameters generated information in a type and form which could be applied by policy makers and pollution managers.

Charter (1992, p.63) defined a stakeholder as "a person or group that can influence the commercial existence, viability and direction of a company." The current concept recognises that stakeholders' interests, concerns and needs extend to corporate environment policy and performance as well as other key business objectives. The corporate environmental movement was greatly strengthened following the *Exxon Valdez* Alaska oil spill of March 1989, which led to the launch and adoption of the Valdez Principles by The Coalition for Environmentally Responsible Economies (CERES). This approach to environmental protection, involving a broadening of the range of instruments beyond legislation to voluntary self-regulation through continual improvement, requires a clear understanding of existing and expected environmental management information needs (Azzone *et al.*, 1996; Welford, 1996).

Greater pressures for improved environmental performance on the part of shipping are evident from an increasing number and diversity of the industry's stakeholder groups. These have been identified for each of the specified vessel-source marine pollutants (Tables A3.1, A3.2 & A3.3), and information requirements of each stakeholder group, and subsequent applications, are defined. A number of different perspectives have been adopted in this analysis including risk-based approaches, assessments of sensitivities of some environmental receptors and product-based assessments. Examples are given for each.

Historically, policy makers at governmental and inter-governmental levels have responded to stakeholder pressures by developing the necessary frameworks for the introduction of

treaty and non-treaty instruments. These seek ultimately to eliminate and prevent vessel-source marine pollution. Therefore, shipping and shipping operations have been subject to an increasingly more stringent international legislative framework under the auspices of the IMO.

To protect sensitive coastlines, international discharge zones have been delineated and different limits specified, usually on the basis of distance from nearest land, and other factors. For example, regulation 3(1)(a) contained in Annex V to The International Convention for the Prevention of Pollution from Ships 1973, as modified by the 1978 Protocol thereof (MARPOL 73/78), prohibits the disposal into the sea of all plastics. Minimum distances from nearest land are stipulated for the disposal of other materials including dunnage, lining and packing materials which will float (25 nautical miles), and food waste and all other garbage (12 nautical miles) (IMO, 1997b).

Contracting Parties to the appropriate conventions are also required to ensure the provision of adequate facilities for reception of operational wastes ashore. In waters around the British Isles the long-term benefits of these regulations, and subsequent amendments, have yet to be evaluated especially in those zones where zero discharge requirements are in force or proposed. For example, at the 39th session of the IMO's Marine Environment Protection Committee (MEPC), a proposal was submitted to identify North West European Waters as a Special Area for MARPOL Annex I (MEPC, 1996).

Accidental spills and cargo losses have been addressed through improved preventive measures relating to, *inter alia*, vessel design, construction, management and operation. Evaluation of the effectiveness of these risk reduction strategies are in part dependent upon empirical approaches to risk assessment. These in turn require accurate and comprehensive statistics on the causes and consequences of casualty-spills and other information (Cole-King & King, 1995).

In the United Kingdom, the Board of Trade, followed by the Department of Transport (DTp) and more recently the Department of Environment, Transport and the Regions, have been responsible for the development and application of shipping policy. At the present time the Marine Safety Agency (MSA) and the Coastguard Agency are responsible for

dealing with day-to-day issues including actual enforcement of regulations and co-ordination of responses to marine pollution incidents. Historically, the DoE and maritime local authorities have been responsible for planning and undertaking shoreline clean-up operations. Port and harbour authorities regulate the conduct of vessels within their respective areas of jurisdiction.

Information requirements of the authorities in connection with reduction and prevention of the specified vessel-source pollutants fall within three broad categories as follows:

(i) To understand the nature and frequencies of pollution incidents for the purposes of determining the adequacy of the organisation and resources to respond.

(ii) To identify deficiencies within existing regulatory frameworks including enforcement procedures, types of sanctions and levels of penalties imposed.

(iii) To help ascertain the adequacy of port reception facilities for ships' wastes and to remove any disincentives for their use.

Further details, with specific examples, are given in Tables A3.1, A3.2 & A3.3.

Environmental and safety management systems based upon proactive strategic positioning and self-regulation have generated additional information requirements on the part of industry associations, their members and other individual corporate stakeholder groups. In the context of the shipping and packaging sectors, numerous collective and individual initiatives have been introduced over the last 30 years in the field of marine pollution prevention and control. The aims of these voluntary undertakings is to anticipate and prevent further legislation being imposed and to promote best practice through the attainment of corporate goals, policy objectives or targets by various codes, guides, charters and related initiatives.

Recent developments include the means of more effectively managing environmental and safety risks through shipboard management systems utilising performance indicators. For example, the International Chamber of Shipping's (ICS) Code of Practice on Shipping and

the Environment, launched in 1993, has provided an operating framework for member companies to improve their environmental performance by having in place management principles to effect such improvement (ICS, 1997). Similar approaches include the development of Formal Safety Assessments (FSA) and the International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code), which is now a mandatory requirement under the International Convention for the Safety of Life at Sea (SOLAS) Convention, 1974 (Bergmeijer, 1996).

In seeking long-term solutions to the marine litter problem, some packaging manufacturers have redesigned their products and established on-going environmental assessments to measure expected environmental benefits. An essential pre-requisite to this approach is the generation of representative and reliable information which enables end-users to act upon the information received and to monitor progress. An appropriate case study is identified in Table A3.3.

An increasing number of environmental non-governmental organisations (NGO's) are regularly mounting campaigns calling for enhanced levels of safety and environmental protection in shipping operations. An essential element in many of these campaigns, which are designed to raise awareness amongst other stakeholder groups, is some form of assessment of the general levels of vessel-source discharges to both coastal and oceanic waters. Source-specific information is required which clearly identifies the contribution of shipping to the overall levels of marine pollution, and trends over time. For example, the World Wide Fund for Nature (WWF) has recently extended its campaign to encourage the adoption and use of Pollutant Release and Transfer Registers (PRTRs) as a new tool to achieve reductions of marine pollution (Ball, 1996).

Therefore, against a background of marine environmental protection becoming a more important international issue requiring responses on the part of an increasing range and number of stakeholder groups, a work programme was formulated and implemented during the 1970's. This focused primarily upon long-term assessment studies of three vessel-source marine pollutants, of which packaged harmful goods and garbage were subjected to regulatory controls for the first time following the adoption of MARPOL 73/78. The required levels of long-term funding to support this work programme, which to date have

exceeded £250,000, were secured under the auspices of the Tidy Britain Group (TBG) and the Advisory Committee on Protection of the Sea (ACOPS).

4.0 DEVELOPMENT OF AN INTEGRATED REPORTING SYSTEM FOR VESSEL-SOURCE MARINE OIL POLLUTION

During the 1970's most measurements of oil in the UK marine environment were intensive, localised and short-term in the context of significant oil spills (Central Directorate on Environmental Pollution, 1979). Following a series of tanker-casualty spills, including the wreck of the *Amoco Cadiz*, there was renewed international interest in the prevention and control of marine oil pollution (Dixon & Dixon, 1976; O'Sullivan, 1978; Anon., 1979). For example, the Council of Ministers adopted in June 1978 the Action Programme of the European Communities on the Control and Reduction of Pollution Caused by Hydrocarbons Discharged at Sea.

In the United Kingdom the Central Unit on Environmental Pollution recommended that " a group comprising representatives of the oil, ports, shipping and central and local government interests should be set up to make proposals on the collection at both national and international levels of statistics and information on oil transportation and on spills including their causes and clean-up costs" (DoE, 1976, p16). The RCEP noted the dearth of hard evidence on the subject of operational oil spills and discharges and consequently recommended that more work should be done to gather information about the sources of oil at sea (RCEP, 1981).

4.1 Research question

Therefore what was the feasibility of developing and applying an appropriate framework to facilitate the integration of available information on vessel-source oil pollution in the waters around the British Isles?

4.2 Work programme

ACOPS has included information on UK marine oil pollution in annual reports since its foundation in 1952. Prior to 1978 information was derived from questionnaire surveys, and described reported pollution incidents at sea and ashore, primarily in England and Wales. When known, additional details included costs and methods used in clean-up operations and numbers of prosecutions and convictions obtained. Local authority associations, industry associations and wildlife protection organisations identified, and distributed questionnaires to, employees or other individuals with responsibility for matters related to oil pollution. Limitations of this data have been identified and discussed (O'Sullivan *et al.*, 1981; Dixon, 1997).

After consultations with the DoE, objectives for a detailed and geographically comprehensive annual survey, encompassing all pollution sources, were identified as follows:

(i) To enable periodic overviews of coastal oil pollution, its origins, types of oil involved, degree of effort and cost incurred in dealing with it and identification of high risk areas.

(ii) To identify trends in severity of pollution and the degree of response over time.

(iii) To produce data assisting development of oil pollution prevention and contingency plans, thereby allowing the competent authorities to allocate resources where they are most needed.

(iv) To generate statistics linking the number, frequency and size of inputs to various causative and other factors and directing efforts to prevent and minimise marine oil pollution.

The author, with another member of an ACOPS workgroup, carried out all developmental stages of the annual survey (Anon., 1979). Since 1980, the author has been responsible for on-going revisions of survey methods and organisational frameworks, data analysis and

production of annual reports published by ACOPS (for example; Dixon & Dixon, 1984; 1996). Administrative assistance has been provided for distribution of questionnaires and production of annual reports.

4.3 Method of approach

The method of approach adopted by the workgroup was divided into two stages as follows:

(i) To review existing sources and types of data and to evaluate their validity for the purposes of meeting the required objectives;

(ii) To devise and apply an appropriate data collection and management system to integrate data from all relevant sources within a single reporting system, operating on an annual reporting cycle.

4.4 Existing sources and types of data

Difficulties experienced when sourcing and quantifying marine oil pollution have been discussed on numerous occasions in the published literature. These have been identified and summarised, with examples, in Table A4.1. The major problems encountered in the field have been attributed to progressive compositional changes occurring after oil has entered the sea, and concurrently, the effects of redistributive processes brought about by the interaction of physical, chemical and biochemical factors. Moreover, the nature of inputs vary considerably and may be insignificant, chronic or acute, continual or occasional (Cormack, 1983).

Therefore, for purposes of overall assessments a number of different approaches and measurement scales have been applied in practice. For each approach the predominant

physical form of oil or oily residues is identified together with an appropriate measurement method, applications and major limitations (Table A4.1).

At point of source, estimates of actual volumes of accidental oil spills from tankers, combined carriers and barges are recorded on the ITOPF database. Statistical sub-sets have been calculated and published for particular geographical areas, including the North Sea, over different time intervals. Comparable statistics for accidental spills from other types of vessels are less readily available, and agreed estimates do not presently exist. Moreover, these inputs may pose significant problems locally as seepages of fuel oil from bunkers of sunken vessels, if not recovered, may occur over prolonged periods of time. An example is the World War Two wreck of HMS *Royal Oak* in Scapa Flow.

Estimates are also published periodically for operational oil discharge quantities from shipping within particular sea areas. The direct proportionality method employed requires detailed information on the sizes, numbers and trading patterns of all vessels operating within defined geographical boundaries, together with certain assumptions regarding operational practices employed. Statistics derived from these studies, whilst unsuitable for real-time reporting, provide a means of identifying expected discharge levels in relation to existing and future legal requirements. Further details are given in Table A4.1.

An alternative approach is to calculate total hydrocarbon concentrations (THC) utilising analytical detectors which are specific to defined ranges and types of compounds. Background oil concentrations and estimated equivalent standing stocks of oil in the water column from all sources have been calculated (for example; Read & Blackman, 1980; Fileman & Law, 1988). Vessel-source discharges, when quantifiable, have been found to make an insignificant contribution to the overall totals because of the relative quantities of oil involved and the non-localized nature of inputs.

Standing arrangements have been in force for many years obliging masters of ships and civilian and military pilots to report pollution at sea or improper discharges from ships (Anon., 1967; Written Answer, 1969; Lawson, 1970). The arrangements were formalised through established procedures under the 1983 regulations giving effect to MARPOL 73/78 in the United Kingdom. As part of the Integrated Global Ocean System (IGOSS)

guidelines were drawn up to standardise and facilitate sightings of oil slicks at sea from tankers and merchant vessels (Intergovernmental Oceanographic Commission, 1977). Problems encountered through repetitive reporting of the same oil slicks, but by different ships or aircraft, and misidentification (Worrall, 1970; National Audit Office, 1991) have been partially overcome by confirmatory observations. Difficulties have also been reported in differentiating between legal and illegal discharges. This method of assessment has provided a valid means of quantifying spatial and temporal trends in the frequencies of occurrence of vessel-source discharges in both coastal and oceanic waters, particularly in the vicinities of major shipping routes around the British Isles.

In addition to visual observations from ships and aircraft, instrumental remote sensing techniques have been developed and applied in aerial operations for the purposes of oil spill management and routine surveillance of shipping routes (Cormack, 1983). In UK waters the DTp began routine aerial surveillance patrols in April 1988. Flights have been organised in a random pattern around the coastline, with an emphasis on the areas with the highest density of shipping (Committee of Public Accounts, 1991). A number of constraints have been experienced in detecting and identifying vessels illegally discharging oil at sea, particularly under cover of darkness. Moreover, surface slicks and sub-surface oil have not been detected when wind speeds have exceeded 5-6 Beaufort (8.49-13.86 ms^{-1}) (Ijlstra, 1989; National Audit Office, 1991).

At the present time this method of assessment alone cannot be applied as the primary means of establishing the total level of minor pollution arising from vessel-source oil discharges at sea. It has been reported that in the North Sea the number of oil slicks detected per flight has changed little during the 1990's and therefore reservations have been expressed concerning the deterrent effect of routine surveillance flights (Andersen & Niilonen, 1995). Given these constraints, confirmed oil slick sightings in the open sea from all ships and aircraft operating around the British Isles still constitute the primary source of information for the purposes of systematic appraisals.

Reports of oil pollution incidents occurring in the tidal stretches of rivers, within port and harbour areas and the open coastline are generally investigated and confirmed or substantiated by the relevant authorities. Allocation of responsibilities for counter-

pollution operations and other post-spill responses have been identified and reviewed (Anon., 1994). Assessments of sources, circumstances and extent of pollution are generally accurate and comprehensive and some details are regularly published.

Whilst detailed guidelines have been drawn up for standardised monitoring of tar residues on beaches (Intergovernmental Oceanographic Commission, 1984), larger scale visual estimates are subject to numerous sources of error. It has been shown, for example, that the accuracy of visual estimates is largely a function of the amount of time and effort spent to acquire the information, the uses for which the data is intended and the experience of the observer (Owens, 1987). Confirmed observations by the competent authorities constitute the most valid source of information for the purposes of systematic reporting.

In the United Kingdom systematic beached bird surveys commenced in 1966 and were later coordinated on a European scale using standardised methods of observation and recording (Bourne & Bibby, 1975; Bourne, 1976). The proportions of oiled birds to the total number of corpses found on beaches are interpreted as indicators of the scale of pollution in bordering seas and the effectiveness of measures to reduce it (Camphuysen & van Franeker, 1992). The underlying assumption is that oily water residues discharged in accordance with MARPOL 73/78 Annex I regulations can neither lead to pollution on beaches, nor to visible black oil in the feathers of birds (Dahlmann *et al.*, 1994). Examples have been published, such as studies undertaken in the Orkney and Shetland Islands, where it has been demonstrated that policy measures to reduce pollution applied locally have been closely followed by lower oiling rates amongst beached birds (Hubeck, 1992). Details of influxes of oiled seabirds therefore provide a complementary source of information on marine oil pollution, although this may not be a direct relationship (Dixon & Dixon, 1977; National Research Council, 1985).

4.5 Data acquisition and management system

Following a review of comparable scale data collection and management systems employed elsewhere, the existing ACOPS system was extensively revised and amended by the workgroup as follows:

(i) Additional and more specific data-fields were defined (Table 4.1).

(ii) A detailed self-completion questionnaire was designed (Table A4.2) and an accompanying set of guidelines compiled.

(iii) Larger-scale organisational frameworks and administrative schemes were devised and applied for the collection and analysis of data.

Major requirements of the questionnaire were that it should be applicable to oil pollution in its different physical forms, and integrate all available information from different data sources. In practice, minimum levels of resolution defined included the following:

(i) Obvious films or scattered oil lumps extending for distances of less than 1.6 km along the shoreline.

(ii) Irridescent films or silvery sheens observed on the water surface in the tidal stretches of rivers, estuaries and the open sea.

(iii) Estimated pollution volumes in excess of 1 litre in confined docks or waterways.

(iv) Any obvious influxes of oiled seabirds, whether dead or alive.

To identify experienced and qualified respondents, an administrative and organisational structure was devised by the workgroup in which questionnaires were distributed internally by each of 13 different reporting organisations. These are listed in Table A4.3, together with their respective sources of information and the numbers of completed questionnaires returned by each during the 1995 survey.

1. Frequency of occurrence of reported incidents.
2. Frequency of occurrence of reported incidents by marine environmental zones.
3. Extent and amount of reported pollution.
4. Types of oil pollution reported.
5. Reported sources of pollution.
6. Reported circumstances and causes of pollution events.
7. Extent and frequencies of clean-up operations.
8. Methods and techniques employed in counter-pollution operations.
9. Reported fates of oil.
10. Effort and expenditure incurred in counter-pollution operations and other responses.
11. Rehabilitation and other responses by reporting organisations.
12. Prosecutions brought by the competent authorities in the United Kingdom and actions taken by other flag states.
13. Reporting effort on the part of survey respondents.

Table 4.1: Main data-fields published in the ACOPS annual oil pollution survey reports since 1980.

Targeting respondents within different reporting organisations, and issuing guidelines to aid proper completion of the questionnaire, were the primary means employed to ensure an adequate degree of consistency in responses within, and between, annual surveys. These arrangements enabled the identification of individuals to verify information received, determine causes of non-response and provide any further details not available at the time of reporting, such as assessments of impacts of particular incidents, details of any compensation payments made or the outcomes of any legal proceedings initiated against alleged offenders.

To achieve required levels of reliability and accuracy the following procedures are applied annually during data collection and management processes:

(i) Any unaccountable major discrepancies between responses by different reporting organisations for the same incidents are investigated, and corrective actions taken such as identification of local expertise.

(ii) The contents of completed questionnaires are cross-referenced with other sources of information for the same incidents, including vessel-casualty and pollution reports published in *Lloyd's List.*

4.6 Principal findings

The relative success of this approach can be objectively assessed from the overall response rates achieved and from the numbers of questionnaires fully completed and returned; for example, the 1995 statistics were compiled from 937 questionnaires or reports received with an overall response rate of 98% for those organisations dispatching and receiving questionnaires (Dixon & Dixon, 1996). From combined data submitted during the 1993 to 1995 annual surveys 36.9% of reports referred to no pollution observed. Moreover, on those occasions when the accuracy of the ACOPS data has been independently evaluated, no major discrepancies were found following comparisons with the results from other studies such as ship monitoring airborne surveillance flights (Whittle *et al.*, 1982; Cormack & Fowler, 1987).

Since 1979 annual survey results have been identified as the authoritative source of information on the incidence of UK marine oil pollution and published by the competent authorities (DoE, 1994). There has also been a growing demand for the information from other major stakeholder groups identified in Table A3.1; for example, from the DTp in presenting a case for designating North West European waters as a Special Area for MARPOL Annex I at the 39th session of the MEPC of the IMO (MEPC, 1996).

The following general conclusions were drawn from statistics compiled by the author between 1993 and 1995 and published by ACOPS (Dixon & Dixon, 1994; 1995; 1996):

(i) Discharges and spills from all types of vessels, including the disturbance of wrecks, constitute the largest category of incidents in which a source of pollution was identified between 1993 and 1995 (Table A4.4).

(ii) The annual number of confirmed tanker-source pollutions, which have occurred mainly in ports, have declined since 1993 (Table A4.4).

(iii) The majority of reported pollution incidents between 1993 and 1995 occurred in the open sea, followed by ports and harbours (Table A4.5).

(iv) The major sources of confirmed oil slicks in the open sea were attributed to accidental spills of crude oil during oil and gas exploration and production operations on the United Kingdom Continental Shelf (UKCS), and illegal discharges of fuel and lubricating oils from vessels operating in the North Sea and English Channel (Figs. 4.1., 4.2. & 4.3).

(v) Fuel, bunker and other refined products were the most frequently identified types of oil pollution between 1993 and 1995 (Table A4.6).

(vi) Analysis of larger incidents (2 tonnes or more) attributed to vessel-casualties has shown that most were caused by fishing vessels in ports, nearshore waters and the open sea (Table A4.7).

(vii) The modal class for the most frequently reported volumes of pollution was <0.39 t (Table A4.8).

(viii) The "polluter pays" principle is not adequately applied to vessel-source oil pollution because of the difficulties experienced by the competent authorities in obtaining sufficient evidence to prosecute alleged offenders (Table A4.9).

The principal findings from the 1993 to 1995 annual surveys indicated most vessel-source pollution incidents were attributed to two types of illegal discharges from non-tanker vessels. Firstly, generally minor accidental spills caused by human error during bunkering operations in ports and harbours. Secondly, deliberate discharges of fuel oils or sludges from machinery space bilges whilst vessels were underway in the open sea. In most instances pollution was quickly dispersed by natural processes, particularly in the open sea or tidal stretches of rivers. Obvious environmental effects from discharges, including damage to coastal amenities, were reported infrequently. Accidental spills during offshore oil exploration and production activities on the UKCS have become a major source of pollution in the open sea (Figure 4.4). However, the impact of these spills appear to have been considerably less than those predicted because of high natural dispersability of many North Sea crude oils.

4.7 Related and future research

Following a request from the Commission of the European Communities (CEC), ACOPS developed a centralised oil pollution reporting system for maritime member states. A team of three specialists, including the author, was appointed to complete a feasibility study examining the operational needs of the survey (O'Sullivan *et al.*, 1981). Two questionnaire-based pilot surveys were also completed by the author during 1982 and 1983 as part of the study (Wardley-Smith & Dixon, 1982; 1983; Dixon, 1985).

On 1 September 1996 the author commenced an 18 month study, commissioned by the Coastguard Agency, to undertake a more detailed long-term analysis of the ACOPS oil pollution statistics compiled since 1964. The aims of the study are to:

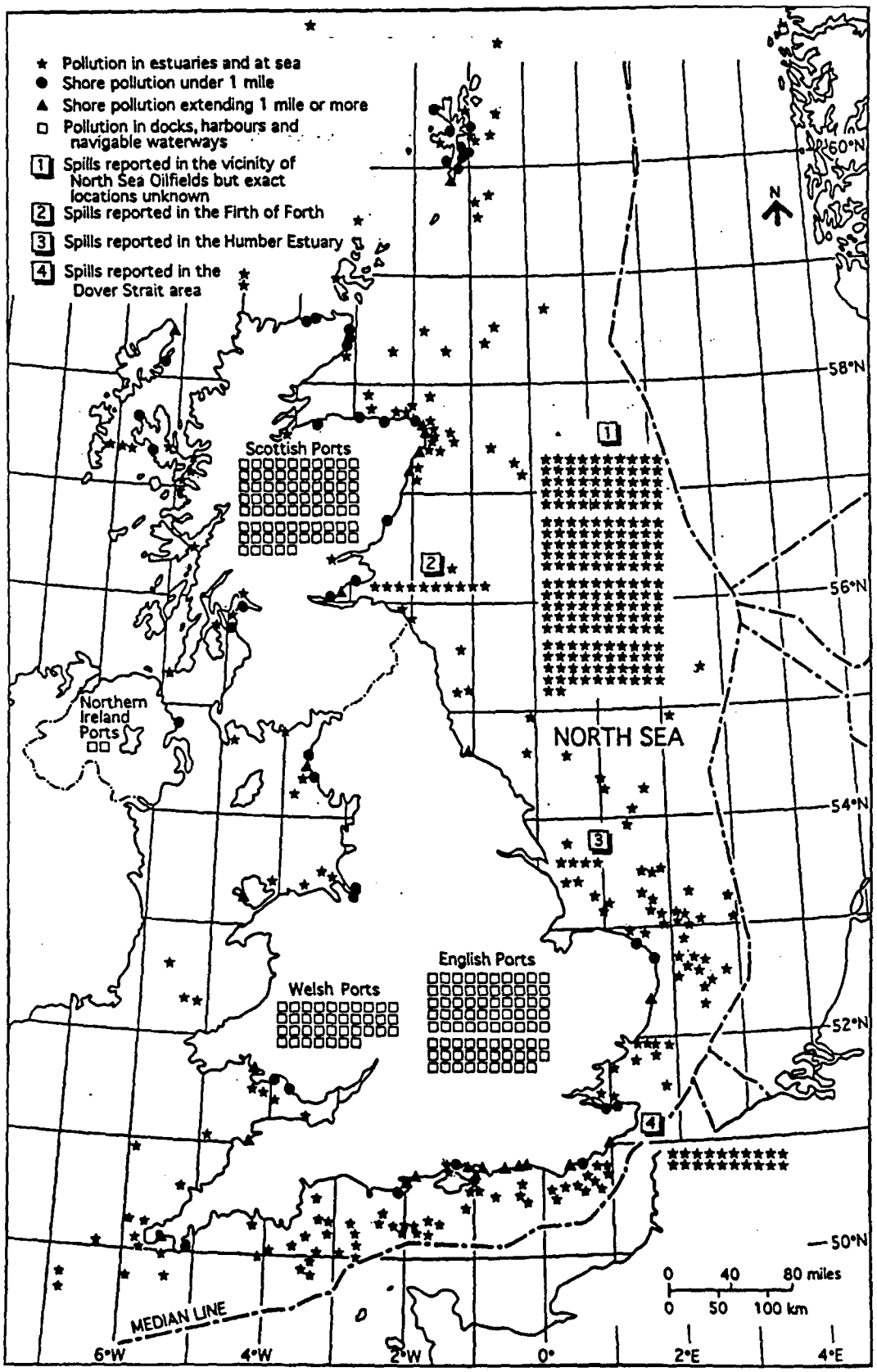


Figure 4.1: The geographical distribution of reported oil pollution incidents 1993. (From: Dixon & Dixon, 1994).

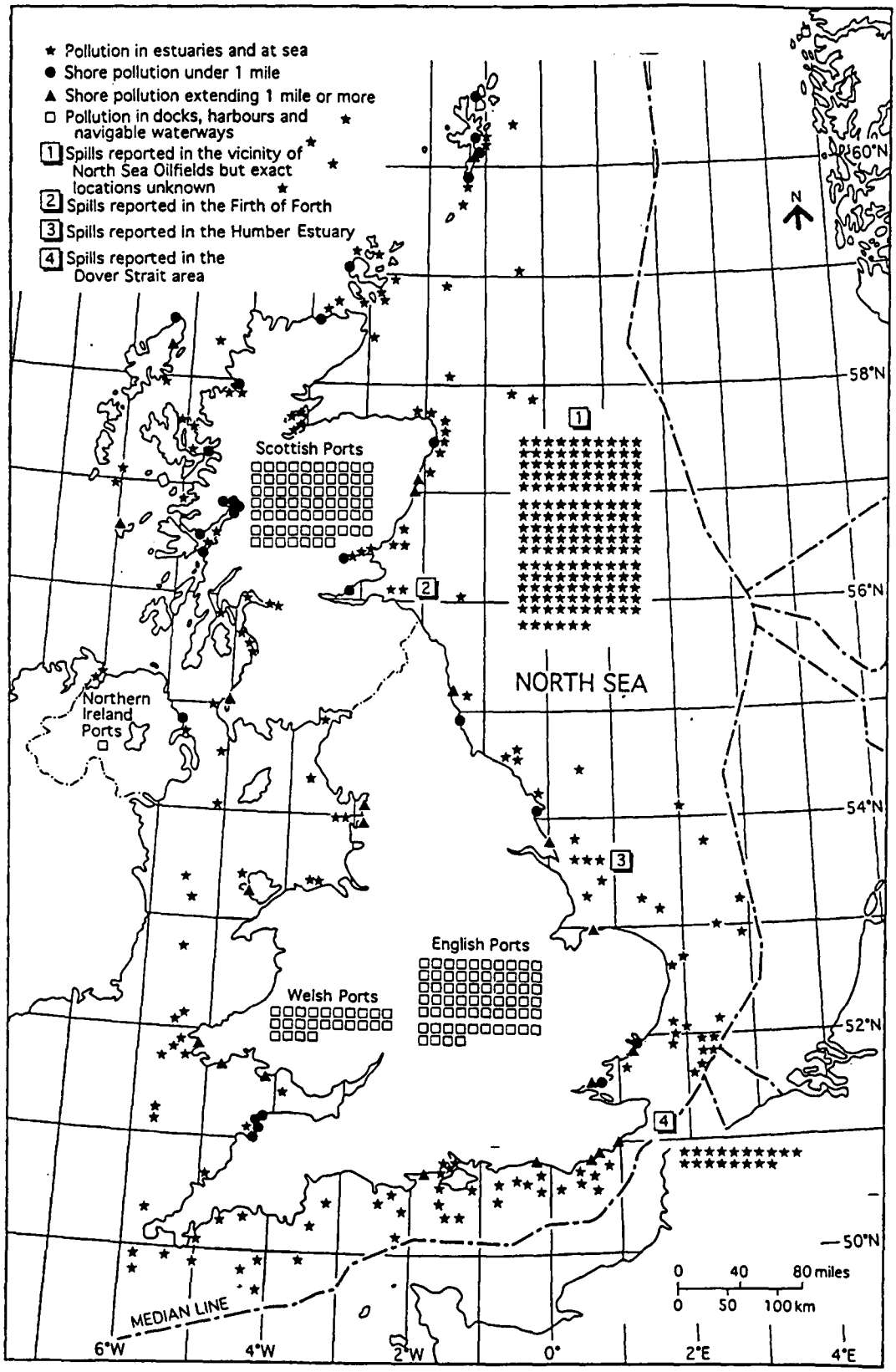


Figure 4.2: The geographical distribution of reported oil pollution incidents 1994. (From: Dixon & Dixon, 1995).

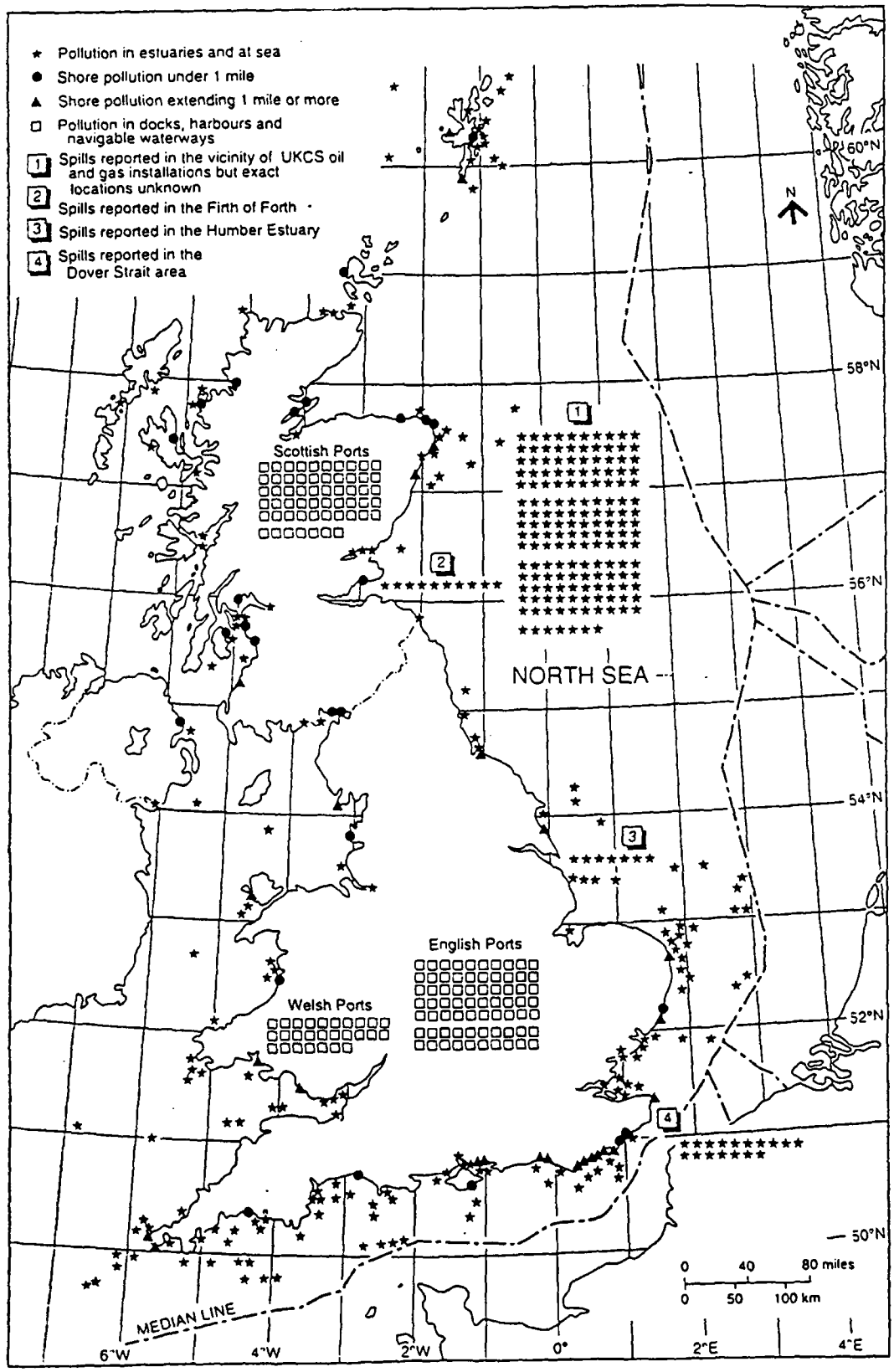


Figure 4.3: The geographical distribution of reported oil pollution incidents 1995. (From: Dixon & Dixon, 1996).

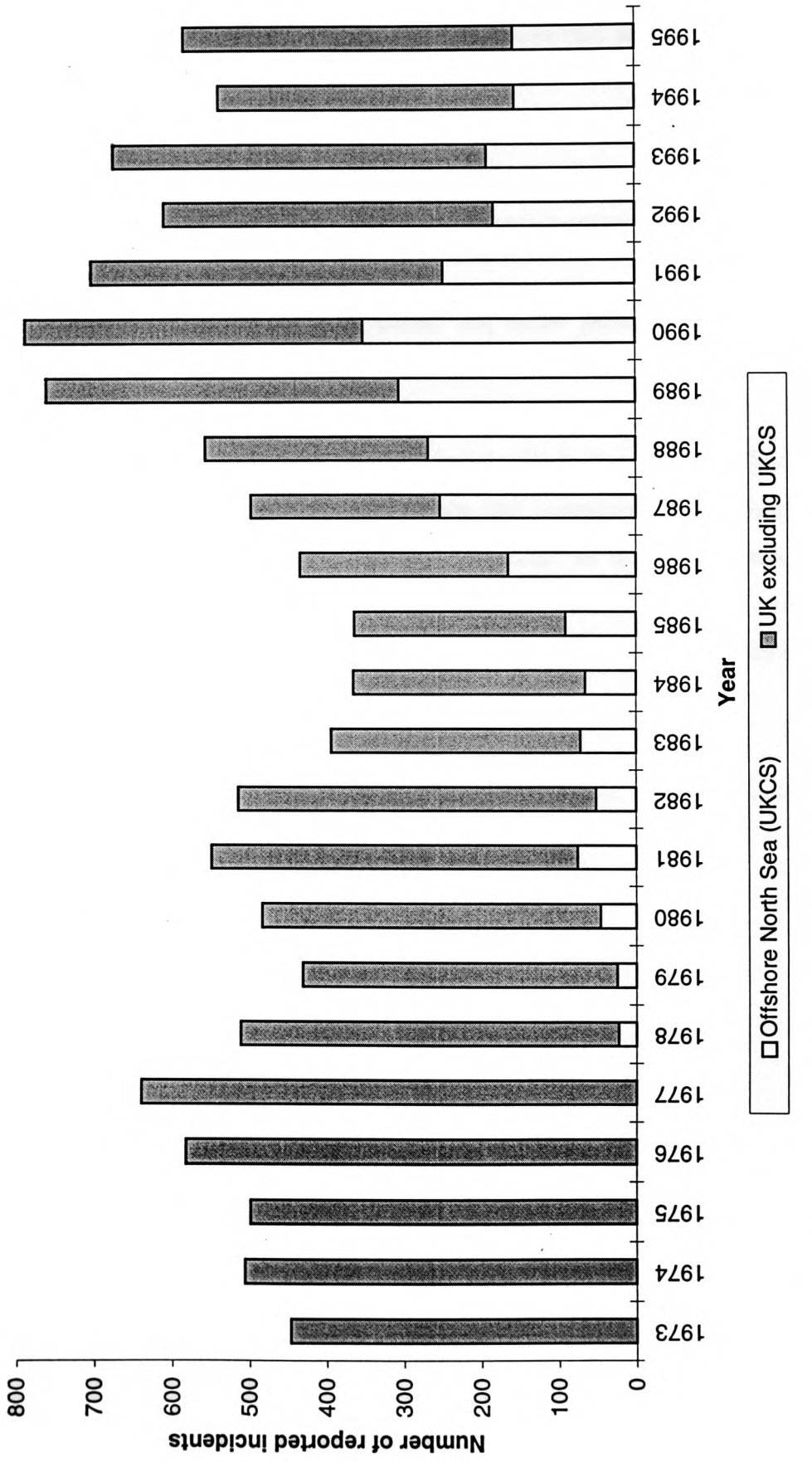


Figure 4.4: Annual oil spill totals for the United Kingdom 1973-1995 (From: Dixon & Mansfield-Williams, 1998)

(i) Ascertain longer term trends in smaller incidental and operational oil discharges to sea from ships and other sources;

(ii) Define; from the trend analyses relevant and appropriate performance indicators for use by the competent authorities in monitoring progress in preventive efforts; and

(iii) Develop a risk assessment model for beach pollution incidents around the UK coastline.

A prioritised work programme was defined in the form of 14 data-fields, listed in Table 4.2, and requiring analyses of comparable and complementary statistics compiled since 1964. Performance indicators will be constructed to meet the general needs of major stakeholder groups. These will include quantitative and qualitative means of measuring progress, setting targets, facilitating benchmarking against best practices and demonstrating any gaps between rhetoric and reality (Dixon, 1997).

1. Frequency of occurrence of reported oil spills.
2. Frequency of occurrence of oil spills by marine environmental zones.
3. Extent and amount of reported pollution.
4. Types of oil pollution reported.
5. Reported sources of pollution.
6. Reported circumstances and causes of oil spillages.
7. Extent and frequencies of clean-up operations.
8. Methods and techniques employed in clean-up operations.
9. Reported fates of oil.
10. Effort and expenditure incurred in clean-up operations and other post-spill responses.
11. Rehabilitation and other post-spill responses by reporting organisations.
12. Prosecutions brought by the competent authorities in the United Kingdom and actions taken by other flag states.
13. Reporting effort on the part of survey respondents.
14. Nature and degree of pollution threat.

Table 4.2: List of data-fields defined for the long-term analysis of oil spill statistics. (From: Dixon,1997).

5.0 DEVELOPMENT OF ASSESSMENT METHODS FOR INCIDENTS INVOLVING PACKAGED DANGEROUS/HARMFUL GOODS LOST AT SEA

In the aftermath of the wreck in 1967 of the *Torrey Canyon*, increasing attention was directed towards the potential problems encountered in responding to vessel-casualties involving other noxious or hazardous substances, notably pesticide cargoes (Select Committee on Science and Technology, 1968). Following a number of comparatively minor incidents around the British coastline, the DoE advised local authorities, in Circular 201/74, to extend their oil pollution contingency plans to include chemicals washed ashore (DoE, 1974). Corresponding advice was issued by the Welsh Office and Scottish Development Department. In planning required response systems, priority was given to safeguarding human health followed by environmental protection.

In a report submitted to the DoE, and later the RCEP, the Isle of Wight County Council documented for the first time actual safety hazards arising from individual, or small numbers of, unmarked chemical packages arriving on the island's beaches during the winter of 1976/77 (Horsnell, 1977). A series of incidents in which packaged chemical cargoes were lost off the Dutch coast during the latter half of the 1970's prompted greater interest in this type of marine pollution. The substances included the IMDG Code Class 2 gases ethylene oxide (flammable & poisonous) and chlorine gas (marine pollutant), and the Class 8 corrosive sulphur dichloride (Koops, 1988). Given the nature of the seaborne chemical package trade, which involves many thousands of different substances, a demand for more information on all aspects of accidental cargo losses has been documented from 1972 to the present day (Anon., 1972c; Horsnell, 1980; Peet, 1984; GESAMP, 1990; Johnston *et al.*, 1994; Law, 1994). Interests of the relevant stakeholder groups regarding this issue have been identified in Table A3.2.

5.1 Research question

Against a background of an increasing need to more effectively address safety and environmental threats posed by chemical cargoes lost at sea, the research question was to establish more precisely the nature and extent of problems attributable to goods in packaged form. Additionally, to develop a suitable framework to facilitate an on-going evaluation of the effectiveness of existing or future preventive controls at all points in the packaging and transportation chain of these substances.

5.2 Work programme

After securing funding from ACOPS and TBG, a work programme was drawn up by the author in 1978 with the following objectives:

(i) To develop and apply relevant data collection and management systems to determine the nature of packaged chemical incidents affecting the nearshore waters and the coastline of the British Isles.

(ii) To identify and quantify the likely sources of such materials, including those other than shipping accidents, and to classify incidents according to the types and quantities of substances involved and their respective hazards.

(iii) To review remedial responses on the part of the competent authorities and highlight any problem areas.

5.3 Method of approach

To reach the work programme's objectives the author designed and applied a two stage method of assessment as follows:

(i) Collection and analysis of information from published and other sources describing major incidents.

(ii) Collection and analysis of data drawn from predominantly unpublished sources describing minor incidents over selected time-intervals.

Major incidents were defined as those caused by losses of substantial quantities of chemical cargoes from ships operating around the British Isles, necessitating a co-ordinated response by the authorities in the form of search, recovery or other operations. Examples of major incidents occurring since 1972 are listed in Table A5.1. The primary sources of information identified were HMCG reports, casualty or pollution reports published in *Lloyd's List* (for example, Anon., 1988) and incident reports published by local authorities (for example, Horsnell, 1980; Murray, 1982).

Minor incidents were characterised as those occurring continually, in which single or small numbers of often unmarked packages were recovered on beaches or from nearshore waters, without advance warning. Questionnaire-based surveys were applied to collect data on minor incidents as follows:

(i) England & Wales, 1 September 1982-31 August 1983 (Dixon & Dixon, 1985; 1986).

(ii) United Kingdom, 1 October 1991-30 September 1992 (Dixon, 1992).

Local authority associations, conservation and amenity groups, industry associations and other organisations identified, and distributed questionnaires to, employees or other individuals with responsibility for matters concerning hazardous materials recovered in nearshore waters or on beaches. When contents of packages were identified as dangerous or harmful substances, detailed information was requested concerning *inter alia,* package types, markings, origins and costs incurred in clearance and disposal operations. The terms of reference of both surveys also included other potentially hazardous materials, such as clinical wastes, military and civilian pyrotechnics and explosives ordnance originating from different sources. A copy of the questionnaire employed in the 1991/92 survey is

given in Table A5.2, and primary and secondary organisations contributing information are listed in Table A5.3. In practice, most detailed information was derived from operational log entries made by local authority personnel with responsibility for identification and disposal of suspicious packages reported on beaches.

5.4 Principal findings

The data collection and management systems applied by the author produced reliable and valid data subject to the constraints, and other limitations identified (Dixon & Dixon, 1985; 1986; Dixon, 1992). The strengthening of preventive and precautionary measures, and their enforcement procedures, summarised in Table A1.1, have apparently led to a reduction in major chemical incidents around the UK coastline. However, the authorities have experienced some recurring problems during search, recovery and related operations. These have been identified and summarised in Table A5.4, and later reported independently elsewhere (Peet, 1988). For example:

(i) Inaccurate or delayed information on the nature and hazardous properties of lost cargoes (*Forum Hope,* 1984 & *Nordic Pride,* 1991).

(ii) Damage to packages following immersion in the sea causing leakages of contents (*Dana Optima*, 1984 & *Sherbro*, 1993).

(iii) Recovery of packages without required markings and labels (*Aeolian Sky*, 1979 & *Fathulkhair*, 1990).

In addition, the practice of handling and shipping dangerous/harmful substances in larger primary receptacles or transport units, and secondary transport units such as dry freight containers, has led to correspondingly greater safety and environmental risks following accidents (Dixon, 1989a; 1989c; Norfolk Standing Emergency Services Working Group, 1991; Law, 1994).

The contents of suspicious packages reported during the two questionnaire surveys of minor incidents have been previously identified (Dixon & Dixon, 1985; 1986; Dixon, 1992). Details of substances subsequently found to possess dangerous properties in the 1982/83 survey, and dangerous/harmful properties in the 1991/92 survey, following the classification of marine pollutants, are given in Tables A5.5 - A5.12 inclusive.

Following comparisons between the 1982/83 & 1991/92 survey results the following broad conclusions were drawn from the data:

(i) Fewer packages were found to contain dangerous/harmful substances during the 1991/92 survey, with a 63% reduction in England & Wales (Table 5.1).

(ii) By their primary hazardous properties, the apparent reductions were most marked for flammable liquids, oxidising substances or agents and corrosives (Table 5.2).

(iii) Potential safety hazards posed by the recovered substances, defined by reference to IMDG Code Packaging Groups and the numbers of packages classified in each group, declined between surveys (Table A5.13).

(iv) There was no evidence to demonstrate any noticeable improvements in required marking and labelling standards between surveys, indicated by the relative proportions of packages with clearly visible IMDG Code Hazard Class labels (Table 5.3).

5.5 Future research

Further studies will be undertaken by the author to determine any significant changes attributable to recent and future developments. These include amendments to the IMDG Code, strengthening of ship reporting requirements and the adoption of the International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances (HNS) by Sea. Greater emphasis will be placed on the

Package contents category	England & Wales 1982/83[a] n	%	United Kingdom 1991/92[b] n	%
Packages found to contain dangerous/harmful goods including those not fully identified at the time of reporting	131	52	52	21
Packages found to contain substances not listed specifically in the IMDG Code	36 [c]	14	42	17
Packages found to contain refined or waste petroleum products	42	17	107	42
Packages awaiting identification	45	17	52	21
Totals	**254**	**100**	**253** [d]	**100**

[a] From: Dixon & Dixon (1985).

[b] From: Dixon (1992).

[c] Includes 21 packages containing substances with suspected dangerous constituents.

[d] Another 62 packages were later found to contain seawater and 111 were empty.

Table 5.1: Summary statistics showing contents categories of packages reported during surveys of minor chemical incidents.

IMDG Class	England & Wales 1982/83[a]		United Kingdom 1991/92[b]	
	n	%	n	%
Class 1: Explosives	-	-	1	2
Class 2: Gases	7	5	2	4
Class 3: Flammable liquids	19	15	10	19
Class 4.1: Flammable solids	2	2	-	-
Class 5.1: Oxdising substances	51	39	2	4
Class 6.1: Poisonous (toxic) substances	8	6	9	17
Class 8: Corrosives	44	34	25	48
Class 9: Miscellaneous dangerous substances and articles	-	-	3	6
Totals	**131**	**100**	**52**	**100**

[a] From: Dixon & Dixon (1985).

[b] From: Dixon (1992).

Table 5.2: Summary statistics showing reported primary hazardous properties of dangerous/harmful substances reported during surveys of minor chemical incidents.

Label identifying IMDG Code Hazard Class	England & Wales 1982/83[a]		Kingdom 1991/92[b]	
	n	%	n	%
Present	75	59	27	53
Absent	42	33	14	27
Not known or reported	11	8	10	20
Totals	**128** [c]	**100**	**51** [d]	**100**

[a] From: Dixon & Dixon (1985).

[b] From: Dixon (1992).

[c] Excluding 2 incomplete reports and a single package of paraformaldehyde for which no label was required in the 25th amendment of the IMDG Code.

[d] Excluded a single Class 9 substance for which only a marine pollutant mark was required.

Table 5.3: Summary statistics showing reported occurrence of IMDG Code hazard class labels on packages containing dangerous/harmful substances recovered during minor chemical incidents.

application of survey results in the form of performance indicators for the chemical and shipping industries, following initial definition of relevant parameters (Dixon, 1994). Attention will also be given to assessments of operational discharges arising from transportation of chemical cargoes in bulk form. This is because of more frequent reports of residues observed on beaches and on the plumage of seabirds (Camphysen & van Franeker, 1992). Previous assessment methods used to study munitions in British coastal waters (Dixon & Dixon, 1979; Dixon, 1992) will be repeated to determine any future differences from past trends.

6.0 DESIGN AND APPLICATION OF ASSESSMENT STUDIES TO MEASURE VESSEL-SOURCE MARINE LITTER

An obvious impact of marine litter is aesthetic degradation of coastal amenities, particularly beaches used for leisure and recreational purposes. When setting a 1971 objective for clean coastal waters and beaches for sport, recreation and amenity, the Secretary of State for the Environment called for adequate information to support necessary improvements (Anon., 1972a). Some coastal local authorities, especially in southern England, responded to increasing amounts of marine litter by extending routine cleansing operations outside the bathing season (Clark, 1987). The marine litter issue was also addressed by the RCEP which noted substantial costs incurred in beach cleaning operations (RCEP, 1984; 1985). Consequently, the Government "recommended voluntary compliance with the provisions of Annex V of MARPOL, pending its entry into force"(DoE, 1984, p12).

6.1 Research question

The early 1970's research question was the feasibility of designing and applying methods to assess different sources of marine litter, in particular amounts attributable to uncontrolled discharges of garbage from all types of vessels operating in waters around the British Isles. Major factors to be considered included assessment strategy types, field sampling designs, measurement scales and analytical techniques. An objective means of measuring expected accumulations of plastics wastes in coastal and oceanic waters was also required.

6.2 Work programme

With support from TBG, the author initiated a Marine Litter Research Programme (MLRP) during 1973 in response to increasing stakeholder concerns, which have previously been identified in Table A3.3. Initial objectives of the programme were to:

(i) Generate accurate and representative statistics from standardised methodologies and analytical techniques showing major sources of marine litter over varying spatial and temporal scales.

(ii) Assess major trends concerning quantities, sources and types of marine litter in relation to the strengthening of national and international controls.

(iii) Determine rates of accumulation of plastics wastes in coastal and oceanic waters around the British Isles, and measure any major changes over time.

After careful consideration of different assessment strategy options available, the author selected a beach focused programme as a primary means of investigation. Relative merits of the different options, including at-sea programmes and characterisation of the dynamics of shipboard generated solid waste streams have been discussed elsewhere (Dixon, 1989b; Dixon & Dixon, 1981b; Horsman, 1982; National Academy of Sciences, 1975b; Ribic *et al.*, 1992). The chronology of major stages in the MLRP is outlined in Table A6.1, together with primary aims and methods of approach adopted.

During the early 1970's there were few references in the published literature describing systematic studies of marine litter. Therefore pilot studies were carried out by the author in a representative study area, situated on the shores of the Dover Strait, to develop beach survey techniques and analytical methods. Containers were selected as suitable indicator items to identify major sources and subsequent movements of vessel-source marine litter. Technical support networks were established with packaging and product manufacturers globally for the purposes of utilising container markings and other characteristics to determine their life-histories; for example, the countries or larger geographical areas in which containers were manufactured or marketed, fabrication materials and relative or absolute ages (for example, Fishman, 1994). The information presented in Tables A6.2 & A6.3 and Plate 6.1 demonstrate the application of this method of enquiry to container samples recovered on the shores of the English Channel and North Sea.

Having selected a realistic and practical assessment strategy, and designed a set of measurement methods and analytical techniques, the author applied them in beach surveys

elsewhere to determine their validity under different conditions. Volunteers recorded details of all containers found in beach transects at 797 different sites around the coastline of the United Kingdom. In addition, three study areas were delineated on the shores of the English Channel, North Sea and North Atlantic Ocean. Each was selected using common criteria, primarily close proximity to major shipping routes and fishing grounds, open coastal conditions, presence of predominantly sandy beaches and frequent onshore winds. Sampling intervals were chosen following periods of onshore winds and avoided any substantial presence of bathers or other beach users and their litter. In total, measurements were taken from litter samples examined on 130 sampling units by the author and field assistants.

To provide further information on movements and fates of plastics containers discharged at sea, the author made a major contribution to the design and application of 6 surface drift experiments. A total of 2,180 sealed bottles was released at dropping points across the North Sea, Strait of Dover, English Channel and Irish Sea between April 1979 and August 1981 (Table A6.4). To aid recovery a robust transparent polyvinylchloride (PVC) bottle design was selected (Fig. 6.1) with clearly visible overprinted text (Plate 6.2). In addition, the author assisted in the design and application of an open-water sighting marine litter survey in representative areas of the North Sea. A strip-transect survey design was employed to generate data showing the composition and densities of floating litter.

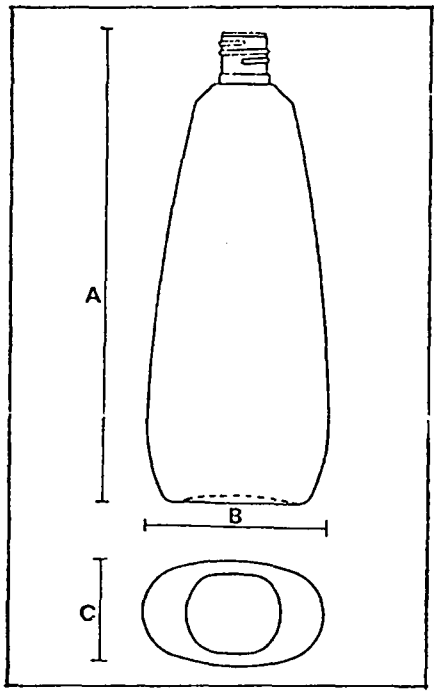
Following a detailed review by the author of knowledge and experience gained from previous studies, and in anticipation of the entry into force of the regulations contained in Annex V to MARPOL 73/78, the programme's objectives were revised. This required beach survey data of specific types of litter organised in an appropriate time series to document improved waste disposal practices at sea. Consequently, a national ocean-focused vessel-source beach litter assessment study was designed by the author utilising comparisons of paired data sets compiled from observations on the same sampling units.

Between 1980 and 1987, prior to the entry into force of the MARPOL 73/78 Annex V regulations, baseline or "before" data sets were taken from beach litter measurements on 185 sampling units organised in 7 study areas around the shores of the British Isles.

Plate 6.1: Year of manufacture and other attributes for selected bottles in the packaging life-history of a dishwashing liquid product.

Plate 6.2: Surface drift bottle with overprinted text.

Following the entry into force of Annex V on 31 December 1988, corresponding "after" data sets were compiled from a second set of identical measurements taken on the same sampling units by the author and field assistants. The time intervals between the "before" and "after" observations were up to 15 years apart (Table 6.1).



Type No.:	1278	
Holpak No.:	B451	
Description:	12 oz. PVC Tall Tapered Oval (Holpak)	
Dimensions:	ins.	mm
A	8.19	207.9
B	3.09	78.5
C	1.70	43.0
Capacity: g.c.v. as moulded	fl. oz. 13.02	cm^3 370

Material:	Food Grade PVC (Impact Modified)
Neck Specification:	24 mm R4
Standard Colours:	Clear (1278)
Bottle weight:	30.5 g

Figure 6.1: Specification for surface drift bottles. (excluding 5.5 g Melinex 1.5 mm wadded urea screw cap).

Number of sampling units	Water mass and study area	Dates of "before" sampling intervals[a]	Dates of "after" sampling intervals[a]
22	North Sea - Mainland Scotland	September 1981	August 1989
23	North Sea - Yorkshire & Humberside	April 1987	April 1998
20	North Sea - East Anglia	April 1981	April 1996
32	English Channel - Isle of Wight	April 1982	April 1991
26	North East Atlantic Ocean - Cornwall	April 1983	April 1992
22	Irish Sea - Cardigan Bay,Wales	April 1985	April 1995
40	North East Atlantic Ocean - Western Isles of Scotland	July 1980	August 1991

[a] Annex V to MARPOL 73/78 entered into force on 31 December 1988 and the North Sea became an effective Special Area for the purposes of of MARPOL Annex V on 18 February 1991 (Table A1.1).

Table 6.1: Locations of study areas and dates of sampling intervals for the national ocean-focused vessel-source beach litter assessment study. (From: Dixon, 1995).

6.3 Principal findings

Overall, survey and sampling designs and associated field measurements applied were found to generate data of sufficient volume and accuracy for the purposes of fulfilling the required objectives. The selected enumeration scales and sampling attributes achieved required levels of resolution in relation to effort and cost constraints. It was therefore possible from various aggregations of data, to construct statistically verifiable hypotheses to identify significant differences between the observed compositional elements and quantities of marine litter.

The following conclusions were drawn from the results of the pilot studies and larger geographical scale surveys completed on the shores of western Europe from 1973 to 1980:

(i) Continuous and widespread inputs of post-consumer primary packaging and other solid wastes to coastal and oceanic waters were evident, and corroborated from a ship-sighting survey of surface floating litter in the North Sea (Table 6.2).

(ii) Following spells of onshore winds wastes were subsequently deposited on beach faces, and highest standing stock mean weight values were recorded on West Jutland sampling units (Table 6.2).

(iii) Containers, notably high density polyethylene (HDPE) lavatory cleanser and household cleaner bottles, glass spirits bottles, metal drums or receptacles fabricated from other materials and filled with petroleum products, aseptic laminated or paperboard milk and fruit juice cartons and wooden or plastic fish boxes, were numerically abundant items of beach litter in all study areas (Table A6.5).

(iv) Analysis of container markings showed a majority of identified specimens collected on sampling units in each study area (except UK national survey) were foreign in origin, with a global distribution of markets and manufacturing sites. (Table A6.6).

Study Area	Sampling Intervals	Number and Types of Sampling Units	Comments
Sandwich Bay, Kent (Dover Strait)	October - March, 1973-1976	116 observations on a 1.6 km stretch of shoreline.	Observations following spells of onshore winds. In total, 2,988 containers examined (36% plastics, 32% glass, 25% metal, 4% paperboard and 1% others). 87% of container samples current production types, 92% <3 yr old & 62% with foreign markings (Dixon & Cooke, 1976; 1977).
Cherbourg Peninsula (North East Atlantic Ocean)	August 1978	Multi-stage stratified semi-random sampling design, observations on 50 sampling units including 5 m wide transects & area searches.	Mean foreshore litter density 27.14 m^{-2} (n=150). 2,460 containers examined (56% plastics, 20% glass, 17% metals, 3% paperboard, 3% others). 91% container samples current production types, 78% <3 yr old & 43% with foreign markings (Dixon & Dixon, 1980).
West Jutland (North Sea)	April 1979	Multi-stage stratified semi-random sampling design, with observations on 40 sampling units including 5 m wide transects and area searches.	Mean foreshore litter density 103.0 g m^{-2} (n=120). 2,849 containers examined (44% plastics, 26% glass, 17% metals, 7% paperboard, 7% others). 87% container samples current production types, 78% <3 yr old & 64% with foreign markings (Dixon & Dixon, 1980).
UK National Survey	June 1978 - October 1979	Volunteers selected belt-transects across shore to waters edge at 797 sites in all parts of the UK.	Widespread distribution of beach litter reported, with details 20,057 containers described in questionnaire returns (42% plastics, 22% metals, 13% paperboard, glass 7%, others 65). 86% current production types & 58% <3 yr old & 17% with foreign markings (Dixon & Hawksley, 1980).
Portugal (North East Atlantic Ocean)	April 1980	Multi-stage stratified semi-random sampling design, with observations on 40 sampling units including 5m wide transects and area searches.	Mean foreshore litter density 5.35 g m^{-2} (n=120). 581 containers examined (63% plastics, 19% metals, 14% glass, paperboard 0.6% & others 2%). 83% containers current production types, 65% <3 yr old & 41% with foreign markings (Dixon & Dixon, 1983b).

Table 6.2: A summary of marine litter surveys carried out on the shores of Western Europe between 1973 and 1980.

(v) Application of two dating techniques to container samples, with known life-histories, indicated a majority were current production types or less than 3 years old when recovered on sampling units in each study area (Tables 6.2 & A6.7).

(vi) Operational discharges of garbage to sea from merchant shipping and other vessels, operating in the coastal and oceanic waters of western Europe, were therefore identified as the primary source of the standing stock of marine litter.

Results from 6 surface drift experiments showed large scale differences in the timing of recoveries on European shores, although most first arrivals occurred within 10 days of release (Table A6.8). Recovery rates were usually greater than 40% for each release batch. Comparisons of observed and expected tracks of first arrivals confirmed that wind was the main factor influencing direction of drift at estimated rates ranging from 2.3% to 26.4% of mean wind speed in the direction of the wind. However, in some nearshore waters strong tidal streams appeared to reduce the influence of the wind factor. In practice, therefore, sealed plastics containers discharged from ships in confined waters such as the English Channel could be stranded on beaches within several days or less. The ship-sighting survey showed that plastics wastes, especially bottles, cups and sheeting were the litter types with the most widespread distribution and highest densities in the North Sea.

Comparisons between the paired data sets for two Scottish study areas provided the first opportunity to:

(i) Assess levels of compliance with the MARPOL 73/78 Annex V regulations, with particular reference to the effectiveness of Regulation 3(1)(a), which from 31 December 1988 prohibited the disposal of shipboard generated plastics wastes anywhere at sea (Table A1.1).

(ii) Identify other major long-term changes in the composition and quantities of marine litter observed on sampling units.

The dates of sampling intervals are given in Table 6.1 and locations of study areas and their respective sampling units are shown in Figure 6.2.

Subject to methodological limits and other constraints identified, there was no evidence from the field data to demonstrate any measurable compliance with the MARPOL regulations for vessels operating in the waters adjacent to both study areas. Analysis of plastics litter weight values on sub-sampling units (Tables A6.9, A6.10 & A6.11), and plastics container counts on sampling units (Tables A6.12 & A6.13), showed no statistically significant reductions between sampling intervals. The same conclusion was drawn from the binary frequency data for occurrence of non-container types of plastics litter on sub-sampling units, which is summarised in Table A6.14 & Figure 6.3.

Further investigation of original contents and types of plastics containers showed disproportionately larger numbers of polythene terephthalate (PET) beverage bottles, HDPE household cleaner and outboard motor oil bottles on sampling units during "after" sampling intervals (Tables A6.15 & A6.16). Direct measurements from dating of plastics container samples indicated a majority had been manufactured after the entry into force of the MARPOL regulations, and therefore had been discharged at sea illegally (Table A6.17).

Analysis of markings indicating geographical origins of plastics containers located on sampling units showed they had been manufactured and marketed in 27 maritime states throughout the world, and a majority were foreign in origin (Table A6.18). However, a major difference between combined "before" and "after" frequency distributions was an increasing proportion of specimens manufactured and marketed in North America, notably Canadian home market outboard motor oil bottles (Fig. 6.4).

The increasing prominence of plastics in litter samples could not be adequately explained by an increased rate of accumulation of these materials at sea or ashore between sampling intervals. No significant differences were apparent between observed ages of bottles for the same product brands between sampling intervals. The relative dating method (n = 984) showed similar proportions of bottles in "before" and "after" samples were current production types (Table A6.19). The absolute dating method (n = 280) indicated the modal class in each of the "before" and "after" bottle samples, for the same product brands, was 2-3 yr with no overall cumulative dissimilarity between age-class frequency distributions (Table A6.17). It was therefore concluded by the author that the increasing prominence of

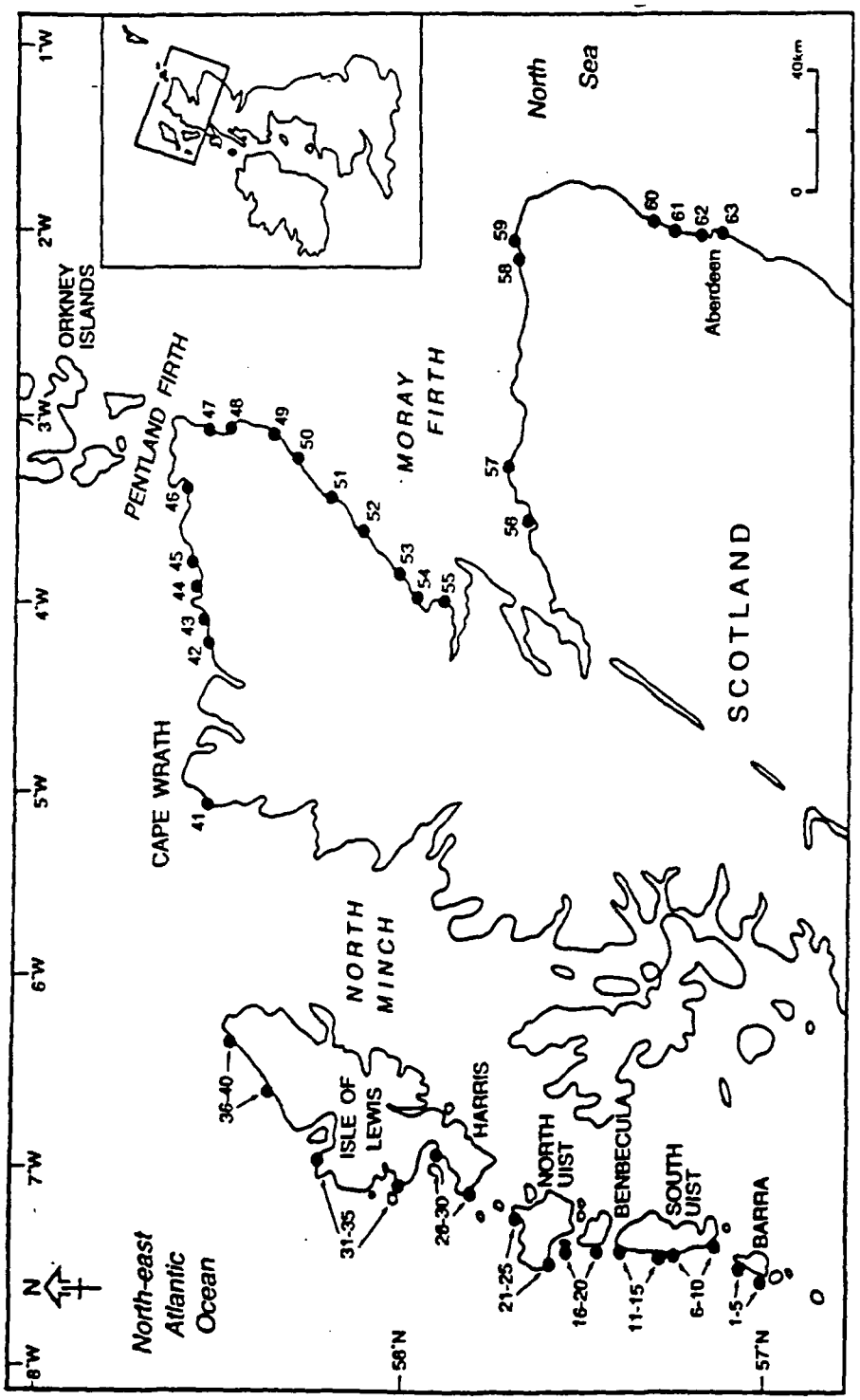


Figure 6.2: Map showing locations of study areas and sampling units in Scotland. (From: Dixon, 1995).

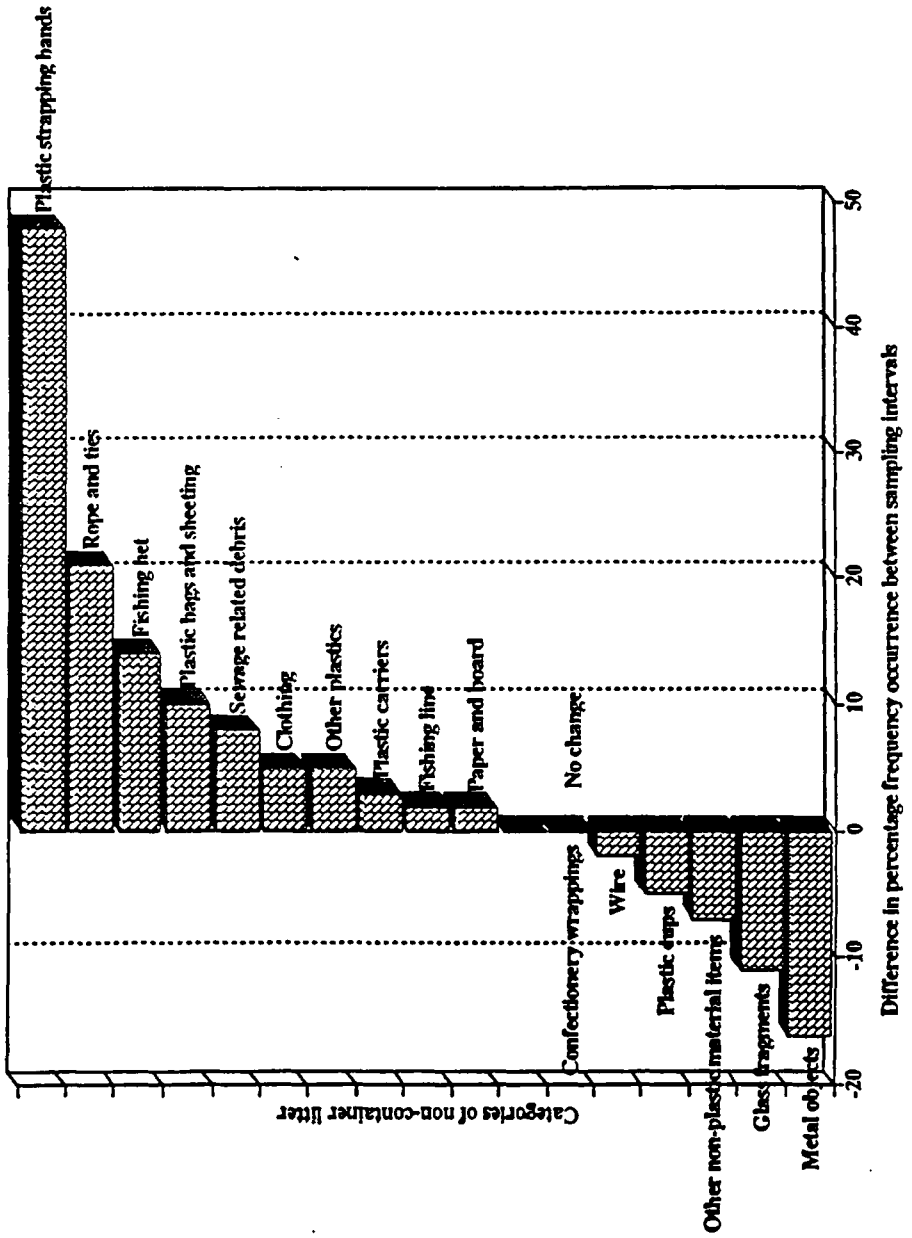


Figure 6.3: Observed changes in the relative occurrence of non-container types of litter between sampling intervals (combined data for Scottish sampling units). (From: Dixon, 1995).

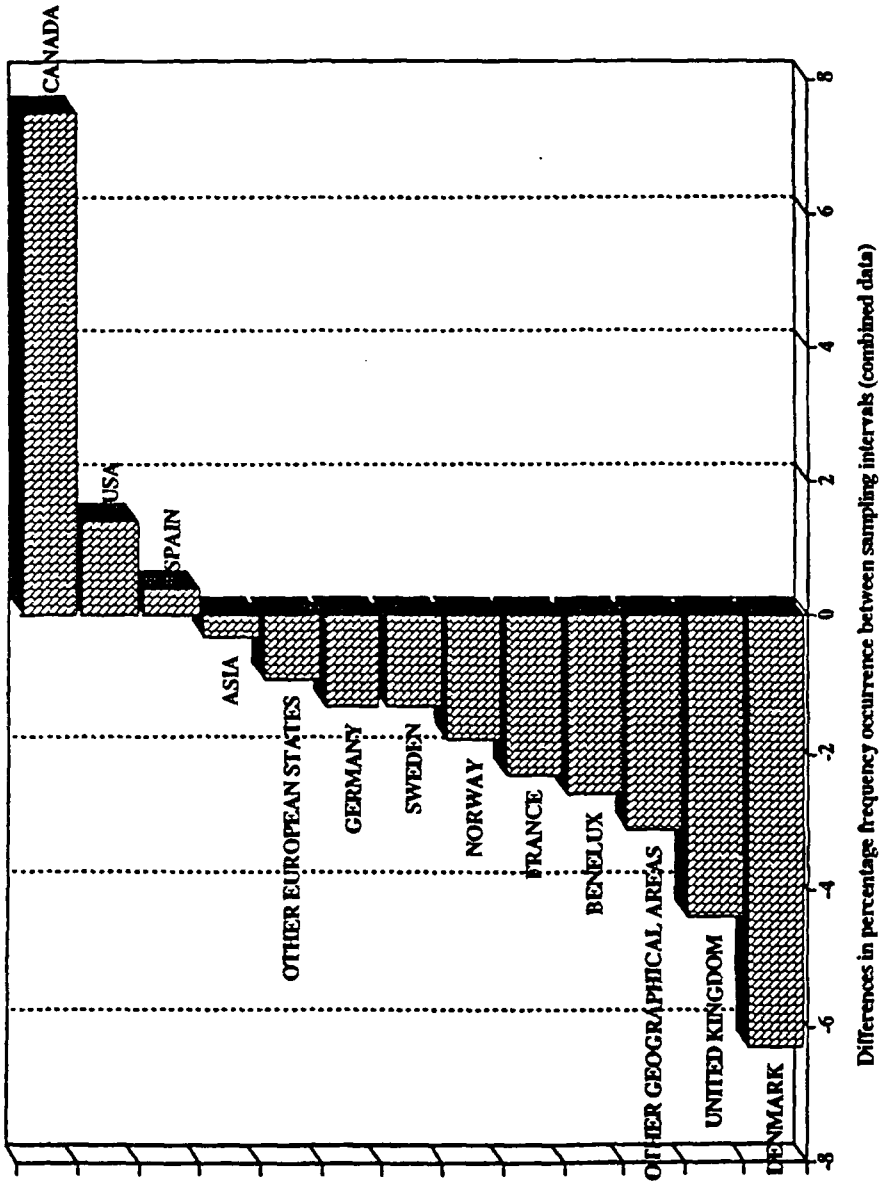


Figure 6.4: Changes in the relative occurrence of plastics containers on Scottish sampling units by their geographical origins (combined data from paired observations). (From: Dixon, 1995).

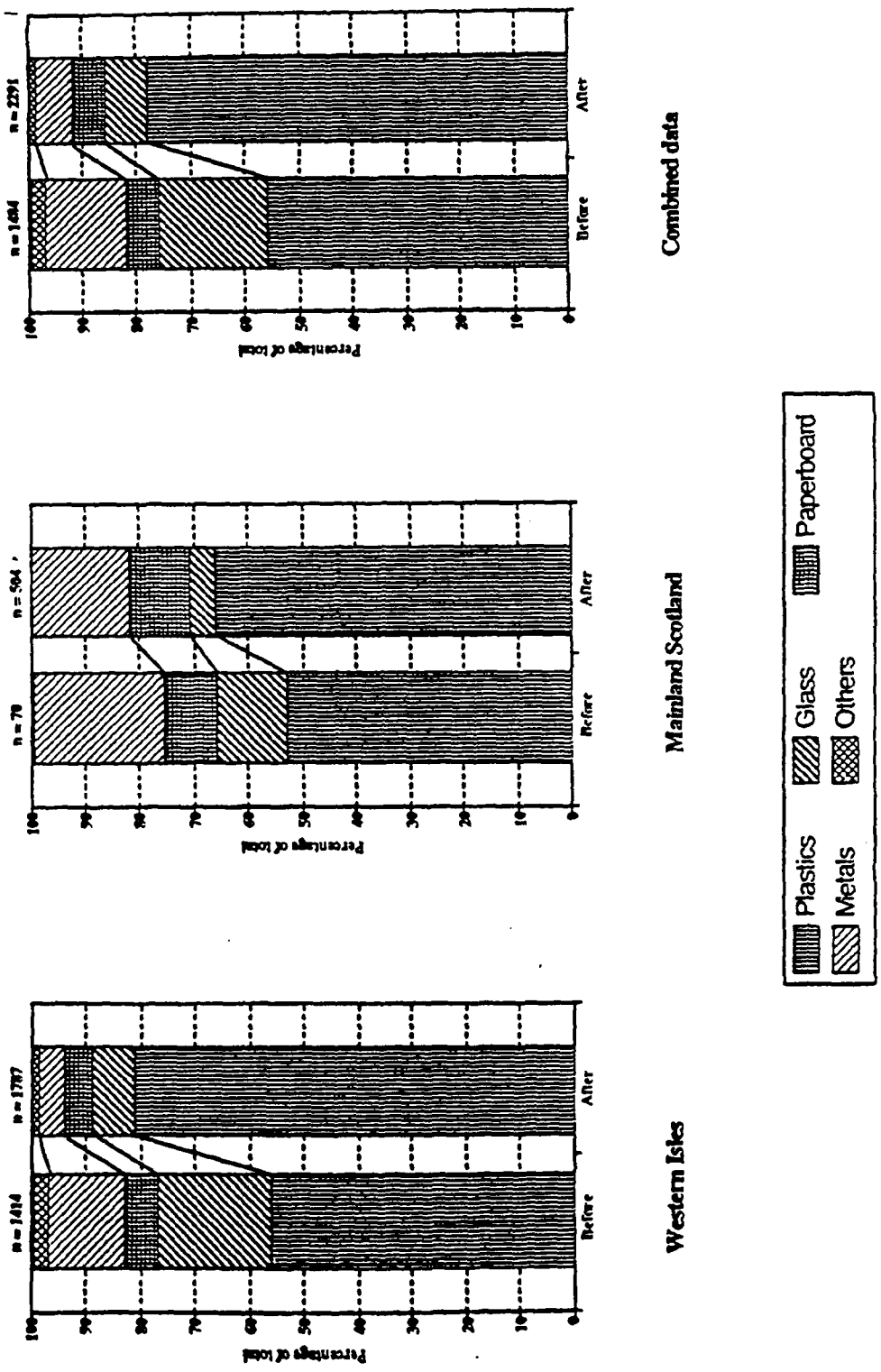


Figure 6.5: Percentage component bar charts showing the composition of Scottish container samples by their primary fabrication materials. (From: Dixon, 1995).

plastics wastes (Fig. 6.5) reflected the greater use of these materials in packaging between sampling intervals.

The published results from different stages of the MLRP have been employed by some major stakeholder groups listed in Table A3.3. For example, by MEPC concerning Annex V to MARPOL 73/78, and by the Code of Practice Advisory Group in the implementation of section 89 of the Environmental Protection Act, 1990 (DoE, 1990).

6.4 Current and future research

The paired data sets taken from remaining study areas are presently being analysed by the author, the findings to be published later utilising the combined data to identify national trends. A third cycle of surveys will commence in 1999 and completed throughout the following decade. The results will facilitate an assessment of the benefits derived from the proposed extension of the present North Sea Special Area for the purposes of MARPOL 73/78 Annex V, to include all North West European waters, and an associated UK requirement for ports to produce formal waste management plans (MSA, 1996). Data sets and other information prepared by the author will be presented to the IMO by the UK Government to help justify the case for the extended special area.

7.0 CONCLUSIONS

7.1 Introduction

In this section some broad conclusions drawn from the research are presented. Firstly, major developments in assessment methodologies for the specified marine pollutants are examined. Secondly, selected assessment methodologies are evaluated in terms of their effectiveness in influencing policy formulation and changes in actual pollution levels. Finally, the section concludes by defining broad objectives for future research.

7.2 Developments in assessment methodologies

Over the last three decades a considerable amount of research effort has been directed towards developments of marine environmental protection strategies. For the purposes of monitoring progress and facilitating more environmentally sensitive management practices, different approaches have been adopted to assess vessel-source marine pollution.

Impact studies have identified lethal and sub-lethal effects attributed to operational and accidental discharges from shipping, particularly at species level. Improved understanding of population dynamics of threatened species has often shown, however, that these effects are not significant in the long term compared with natural mortality factors such as food availability. In the case of British seabird populations, for example, little evidence has been published identifying any long-term threats posed by chronic or acute oil pollution from shipping or other sources, including offshore oil exploration and production activities. Moreover, studies completed by the author have questioned underlying assumptions concerning the value of beached bird surveys in determining the impact of oil pollution upon seabirds.

Another assessment approach has utilised estimated amounts, sources and distributions of both legal and illegal operational discharges from shipping. Major constraints of this

methodological approach applied to pelagic tar and other debris were identified by the author. In addition, risk assessment models have been widely developed to predict occurrences and consequences of accidental oil spills. The limitations of some of these models became evident after they failed to accurately predict fates of large oil spills caused by the grounding of the tanker *Braer* and a pipeline fracture and well blow-out in the North Sea's *Piper, Claymore* and *Ekofisk* fields.

More recently, regulatory authorities have placed greater emphasis on enforcement of discharge limits for shipping operating in international waters. Improved analytical and measurement methods have therefore been developed and applied to identify specific sources of illegal discharges. The application of instrumental remote-sensing techniques during dedicated airborne surveillance flights over shipping lanes has identified more accurately volumes and types of illegal oil discharges. Further advances are expected from the utilisation of satellite imagery in surveillance activities. A feasibility study is presently underway to establish an oil spill database system using imagery from the Canadian *Radarsat* satellite. Two further promising approaches are advanced chemical fingerprinting of petroleum hydrocarbons and development of active tagging systems applied to oily wastes, liquid cargoes and bunkers.

With the passage of time the ACOPS oil pollution survey methodology has proven sufficiently robust to incorporate and integrate data derived from improving assessment methods outlined previously. It has proven more challenging to generate similar robust statistics for garbage discharges from shipping primarily because of difficulties encountered in designing suitable sampling strategies and survey methods. The author has therefore contributed to the design of more refined statistically-based survey designs and analytical methods which clearly identify major sources of marine litter and changes over time.

7.3 Effectiveness of assessment methodologies

Following commencement of the research outlined previously a strong international scientific and political lobby has emerged which has become increasingly effective in

drawing attention to marine protection issues. The author's research findings have contributed to this movement, improving our state of knowledge about sources, levels, fates and effects of vessel-source marine pollution in the waters around the British Isles. The findings have, in turn, been considered by policy makers and marine managers in formulating and evaluating preventive and control management strategies, developing appropriate organisational and operational response mechanisms and defining achievable environmental quality standards.

A major benefit derived from the author's work on marine oil pollution has been to allow policy makers to look at the subject a whole and to review the various components of the problem in proper relationship with each other. Statistics showing volumes and types of operational oil discharges from shipping at sea, and comparisons with beach pollution incidents, have provided guidance in evaluations of the effectiveness of discharge limits to protect coastal amenities. Since the late 1970's, for example, progressive tightening of discharge limits, particularly for cargo wastes from tankers, has resulted in a marked reduction of beach pollution incidents reported in the United Kingdom.

Long-term effectiveness of enforcement actions applied by UK authorities have also been determined by the author from ACOPS data. The major impact of dedicated airborne surveillance flights introduced during the late 1980's has been improved detection of smaller oil slicks. However, the identification rate of offending vessels in the open sea has declined since the flights were introduced. Authorities have therefore concluded that if overflights are to become an effective deterrent the number of hours flown will have to be greatly increased.

Analyses of ACOPS statistics have also identified a limited deterrent effect of prosecutions for oil pollution offences due to generally low levels of fines imposed. Policy makers have responded by increasing maximum levels of penalties imposed by Magistrates' Courts and by including MARPOL 73/78 requirements in port state control inspections of foreign vessels.

The main conclusions drawn by the author from TBG studies highlighted difficulties in organisational and operational aspects of pollution control. In retrospect, actual operation

of Conventions drafted in simple legal terms were found to be difficult to operate in practical terms. Analysis of causes for observed deficiencies in marking and labelling requirements for packaged dangerous and harmful goods identified failures at all stages in the packaging and transportation chain.

Policy makers therefore, operating under the auspices of the IMO, established procedures to ensure that contents of packages were properly identified before carriage by sea. In addition, new standards were introduced to ensure improved durability of packagings and their labelling systems when exposed to marine environmental conditions. To combat general ignorance of regulations a general education programme was introduced which targeted shippers, packers, hauliers and manufacturers of the goods.

Implementation of Annex V to MARPOL 73/78 provides another example of practical difficulties encountered in meeting apparently simple legal requirements. The regulations were adopted in the Convention without clear scientific and technical understanding of practical means of implementation. The TBG studies have therefore been drawn upon extensively by the IMO and national administrations to provide a clearer understanding of types and sources of garbage discharged at sea.

The author's research findings were also examined by the Code of Practice Advisory Group when drafting the Code of Practice on Litter and Refuse under Part IV of the Environmental Protection Act 1990. Whereas cleanliness standards were defined for all other environmental zones, a broad objective only was given for amenity beaches which was to keep such beaches predominantly free from litter and refuse during the bathing season. This was because the Advisory Group noted the author's reservations concerning the practicalities of removing substantial quantities of marine litter from beaches within any reasonable time period during persistent spells of onshore winds.

7.4 Future research

Sustainable development requires an integrated strategy to protect the whole environment and not just one compartment. Policy makers should consider all alternatives and options

for disposal of wastes in which the marine environment is not considered in isolation from all others. In order to select the best practicable environmental option further research is required to more fully understand significant environmental effects arising from disposal of shipboard generated wastes ashore as well as at sea.

The introduction of environmental and safety management systems in the shipping and packaging sectors is discussed in section 2. This approach to attainment of environmental protection goals is becoming more important with a move away from command-and-control towards incentive-based regulation and increasing adoption of voluntary initiatives at corporate level. Transparent and credible performance indicators are therefore required to: provide quantitative and qualitative means of measuring progress; set appropriate targets; facilitate benchmarking against best practice and demonstrate any gaps between rhetoric and reality.

For vessel-source marine pollution, performance indicators could be constructed which address significant changes in long-term threats or hazards posed to wildlife and coastal amenities, impact of improved procedures or operations on amounts or types of discharges and success of preventive measures and enforcement actions. Given the disproportionately large influence of public perceptions of environmental degradation upon the regulatory process, performance measures are required which are based upon direct rather than indirect experiences of marine pollution.

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APPENDIX

Instrument	Date of entry into force	Main requirements
OIL		
International Convention for the Prevention of Pollution by Oil (OILPOL), 1954.		
	26 July 1958	Established "prohibited zones" extending at least 50 nautical miles from nearest land in which discharge of oil and oily mixtures containing more than 100 parts per million (ppm) was forbidden. Required Contracting Parties to take steps to promote the provision of facilities for the reception of oily wastes and residues. Oil defined as crude oil, fuel oil, heavy diesel oil and lubricating oil.
1962 & 1969 Amendments	26 June 1967, 20 January 1978	Operational discharges of oil from tankers restricted and "prohibited zones" extended. New form of oil record book required, recording the movement of cargo oil and its residues from loading to discharge. Conditions on discharge from machinery spaces of all ships including rate of discharge not exceeding 60 litres per nautical mile being travelled by the ship and as far as practicable from land.

Table A1.1: Summary of selected international instruments concerning operational and accidental discharges from vessels. (From: IMO, 1997a).

Instrument	Date of entry into force	Main requirements
International Convention for the Prevention of Pollution from Ships, 1973, as modified by the 1978 Protocol thereof (MARPOL 73/78).		
Articles to the Convention		Parties required to co-operate in the detection of violations. Ships may be inspected by other Parties to detect violations. Incidents involving harmful substances reported without delay, in accordance with Protocol I of the Convention.
Annex I : Regulations for the Prevention of Pollution by Oil	2 October 1983	Definition of oil broadened to mean petroleum in any form, including crude oil, fuel oil, sludge, oil refuse and refined products. Discharge of oil forbidden in "special areas". Parties to the Convention to ensure that adequate reception facilities provided. International Oil Pollution Prevention Certificate to be issued to tankers and other ships. For discharges from machinery spaces of all vessels, the ship must be underway, more than 12 nautical miles from land, and the oil content must be less than 100ppm. All ships of 400 gross tons and above to be equipped with oily-water separating equipment or filtering system for discharges from machinery space bilges and larger ships with oil discharge monitoring and control systems. Oil tankers constructed and equipped to retain oily residues on board for disposal ashore. New tankers provided with clean ballast tank system, (CBT), segregated ballast tanks (SBTs) or crude oil washing (COW). Tankers and other ships to carry and maintain Oil Record Books. Total amount of oil which can be discharged to sea halved for new tankers. Stricter regulations for the survey and certification of ships.

Table A1.1 continued.

Instrument	Date of entry into force	Main requirements
1984 amendments	7 January 1986	Changes to Oil Record Book, piping arrangements for underwater discharges and some regulations waived for ships operating exclusively in special areas or within 12 nautical miles of land.
1991 amendments	4 April 1993	New chapter IV to Annex requiring oil tankers of 150 gross tons and above to carry a shipboard oil pollution emergency plan approved by the Administration of the country whose flag the ship flies.
1992 amendments	6 July 1993	New tanker design and construction requirements introduced to reduce pollution resulting from accidents. In addition, machinery space discharge limits reduced to 15ppm for non-tankers and for all ships built after 6 July 1993, with 5 year period of grace for existing ships (until 6 July 1998). Tanker discharge rate reduced to 30 litres per nautical mile outside special areas.
1995 amendments	3 March 1996	Enhanced programme of inspections applying to all oil tankers aged 5 years and above. Amendments also affecting 4 of the Convention's 5 technical annexes, including Annex I. Make it possible for ships to be inspected when in the ports of other Parties to the Convention to ensure that crews are able to carry out essential shipboard procedures relating to marine pollution prevention.

Table A1.1 continued.

Instrument	Date of entry into force	Main requirements
PACKAGED DANGEROUS/HARMFUL GOODS		
International Convention for the Safety of Life at Sea (SOLAS), 1960 & 1974. Revised Chapter VII : Carriage of Dangerous Goods.		
International Maritime Dangerous Goods (IMDG) Code.	26 May 1965 25 May 1980	Contracting Governments required to issue or cause to be issued detailed instructions concerning the carriage of dangerous goods, and for this purpose the IMDG Code was adopted by the IMO in 1965 and updated periodically. The Code states the basic principles involved in the safe carriage of packaged dangerous goods by sea, with detailed recommendations for good practice for individual substances. Although designed for mariners the provisions of the IMDG Code affect a number of industries as well as storage, handling and transport services.
1991 amendment	1 January 1994	Ships required to carry lists showing the dangerous goods carried and their location. Regulation 7.1. added making it mandatory for the loss overboard of dangerous goods to be reported to the nearest coastal State.

Table A1.1 continued.

Instrument	Date of entry into force	Main requirements
International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances (HNS) by Sea, 1996.		
	Not yet in force	The Convention will make it possible for the equivalent of up to £250 million to be paid out in compensation to victims of accidents involving HNS, such as chemicals. HNS are defined as substances included in various IMO Conventions and Codes. The Convention introduced strict liability for the shipowner, higher limits of liability than the present general limitation regimes and a system of compulsory insurance and insurance certificates.
Annex III to MARPOL 73/78		
Regulations for the Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form.	1 July 1992	Applies to all ships carrying harmful substances in packaged forms, or in freight containers, portable tanks or road and rail wagons. Annex requires the issuing of detailed standards on packaging, marking, labelling, for preventing or minimising pollution by harmful substances. Amendment 25-89 of the IMDG Code became effective on 1 January 1991 and provided the means of implementing the new requirements following the identification of 600 substances identified as marine pollutants.

Table A1.1 continued.

Instrument	Date of entry into force	Main requirements
SHIPS' GARBAGE		
Annex V to MARPOL 73/78		
Regulations for the Prevention of Pollution by Garbage from Ships.	31 December 1988	Disposal into the sea of all plastics prohibited and minimum distances from nearest land stipulated for the disposal of other materials including dunnage, lining and packing materials which will float (25 nautical miles), and food wastes and all other garbage (12 nautical miles). All ports to provide reception facilities. Less stringent requirements for non-plastics materials passed through a comminuter or grinder.
		Disposal into the sea of all types of garbage, except food wastes, prohibited in special areas.
	18 February 1991	The North Sea became an effective special area for the purposes of MARPOL Annex V.
	1 July 1997	Regulation 9 requiring that placards are displayed indicating disposal requirements when sailing in and out of special areas, and that garbage record book and garbage management plan be carried on board.

Table A1.1 continued.

Stakeholder Group	Main information requirements and applications
Policy makers at governmental and inter-governmental levels (including DoE, DTp, IMO & North Sea Ministerial Conferences).	(i) Operational discharges: General levels and distributions of pollution to facilitate the framing of policies and instruments regarding, *inter alia*, the required zonal discharge limits (Example: Part V & Annex III of the Esbjerg Declaration). (Ministerial Declarations, 1995; MEPC, 1996). (ii) Accidental spills: Causes and effects of incidents to assist the development of appropriate preventive measures (including vessel design, construction, management and operation) and risk assessment models (For example: The Marine Accident Risk Calculation System). (Department of the Environment, 1976; Royal Commission on Environmental Pollution, 1981).
Competent authorities (including DTp, Local Authorities & Port Authorities).	(i) Statistics and other information on operational discharges and accidental spillages to assist the development and application of enforcement procedures, sanctions, penalty levels, contingency plans and counter-pollution organisations (For example; Joint Ministry of Housing and Local Government Circular No 34/68 & 29/68, 1968; Local Government Act, 1972). (Royal Commission on Environmental Pollution, 1981; Committee of Public Accounts, 1991). (ii) Complementary information to enable an evaluation of the adequacy of reception facilities for oily wastes and the promotion of best practice (For example; Green Award Certification; Environment Agency's Oil Care Campaign). (Wolters, 1996).

Table A3.1 : The major stakeholder groups and information requirements concerning vessel-source oil pollution.

Stakeholder Group	Main information requirements and applications
Industry associations (including ICS, ITOPF & OCIMF).	Specific and general information on the amounts and circumstances of discharges or spills to demonstrate compliance with legal requirements, the achievement of voluntary targets or objectives, and to influence other stakeholders through various codes, guides and other related initiatives (Examples; International Oil Tanker & Terminal Safety Code, 1972; ICS Pollution Pollution Prevention Code, 1976).
Corporate organisations (including insurers, owners, charterers, bankers, ship managers & underwriters).	The means of avoiding sub-standard or high risk groups of shipping and measures of corporate environmental performance against policy objectives (ICS, 1997).
NGO's and the general public (including The Royal Society for the Protection of Birds & ACOPS).	Direct or indirect assessments on the general levels or risks of discharges or spills from vessels as part of campaign materials calling for the protection of life and the environment from the risk of inadequate shipping practices (Pullen, 1996).

Table A3.1 continued.

Stakeholder Group	Main information requirements and applications
Policy makers at governmental and inter-governmental levels (including DoE, DTp, EC & IMO).	Complete understanding of the nature and consequences of major and minor incidents to enable the strengthening of precautionary measures and other responses (Examples: IMDG Code of the 1974 SOLAS Convention; Annex III to MARPOL 73/78; EC Directive 93/75/EEC) (IMO, 1997(b); Rabbits, 1994).
Competent authorities (including DTp and Local Authorities).	Evidence of any deficiencies in the current regulatory framework for the purposes of improving enforcement procedures through flag state and port state controls, and background information to assist in the planning of search and recovery operations (Examples: Department of Environment, Welsh Office & Scottish Development Department Circulars 123/74, 201/74, 76/1974, 75/1975; Merchant Shipping Notices M 956, M 1023). (Cormack, 1988).
Industry Associations (including ICS & Chemical Industries' Association).	Broad understanding of the effectiveness of existing safety and pollution prevention standards throughout the transportation chain to correct any weaknesses and communicate improvements to other stakeholders (Examples: ICS Environment Code of Practice; CIA's Responsible Care Programme). (Anon., 1993; ICS, 1997).

Table A3.2: The major stakeholder groups and information requirements concerning packaged chemical cargoes lost from ships.

Stakeholder Group	Main information requirements and applications
Corporate organisations.	Relevant information to reduce corporate risk exposure through the development of management tools and appropriate operational systems (For example: International Management Code for the Safe Management of Ships and Pollution Prevention). (Cowley, 1995).
NGO's and the general public (including Coastwatch Europe Network & TBG).	Assessments of the nature and types of actual and perceived risks posed by major and minor incidents to raise awareness amongst other stakeholder groups for improved safeguards (RCEP, 1985; Rees & Pond, 1991; 1992).

Table A3.2 continued.

Stakeholder Group	Main information requirements and applications
Policy makers at governmental and inter-governmental levels (including IMO & UNCED).	Composition, sources and distribution of marine litter to control vessel-source inputs and establish viable alternative disposal routes (Examples: Annex V to MARPOL 73/78 & Chapter 17 of Agenda 21). (IMO, 1997(b); UNCED, 1992).
Competent authorities (including DTp and Port & Harbour Authorities).	Types and amounts of garbage discharged to sea to assist in the evaluation of the adequacy of port reception facilities for all types of vessels and the preparation of waste management plans. (Example: Merchant Shipping Notice M.1659). (Doyle, 1992).
Local Authorities.	Vulnerability of coastline to marine litter depositions to assist in the development of beach cleansing plans in accordance with statutory and other obligations (Examples: cleanliness standards defined for amenity beaches under section 89 of the Environment Protection Act, 1990 and Blue Flag/Seaside Beach Award beach cleanliness criteria). (DoE, 1990; European Co-ordination, 1996).
Industry Associations (including Shipping & Packaging sectors).	Means of assessing overall performance against voluntary undertakings in the form of codes, guides, charters and related initiatives (Examples: Part 4: ICS Environment Code of Practice, Packaging Standards Council). (ICS, 1997; Packaging Standards Council, 1994).

Table A3.3: The major stakeholder groups and information requirements concerning discharges of ships' garbage at sea.

Stakeholder Group	Main information requirements and applications
Corporate organisations.	Information to assist in the development of corporate performance measures relating to the design of products or source reduction initiatives (Examples: ITW Hi-Cone ECO/carrier and Princess Cruises/ P & O Shipping's Total Quality Management). (Anon., 1991; Onions & Rees, 1992; Wade, 1996).
NGO's and the general public (including TBG and The Marine Conservation Society).	Objective and subjective assessments of the marine litter issue for the purposes of raising awareness amongst other stakeholder groups and measuring progress (Examples: Marine Litter Research Programme and Annual Beach-Cleans and Surveys). (RCEP, 1984; 1985; Pollard & Parr, 1996).

Table A3.3 continued.

Physical form of oil	Measurement method & application	Limitations
Crude oil or oil products.	Estimates of average annual inputs over different time intervals from tanker spills above and below 7 tonnes.	Data excludes exceptionally massive incidents and average values depend upon time intervals selected, geographical areas delineated and spill size categories used to group data. No corrections applied for oil recovered during clean-ups or amounts dispersed naturally or artificially (For example: seas around the British Isles; Whittle *et al.*, 1982).
Oil and oily mixtures or residues.	Estimates of oil discharge quantities to sea from shipping in particular areas over given time-intervals.	Requires detailed information on the sizes, numbers and trading patterns of vessels based upon actual experience together with assumptions on operational practices employed (For example: North Sea; Cormack & Fowler, 1977).
Total hydrocarbon concentrations (THC) or dissolved/dispersed petroleum hydrocarbons (DDPH).	Estimation of nominal oil values using analytical detectors specific to specific ranges and types of compounds taken from sub-surface and surface sediment samples.	Difficulties encountered in sourcing and analysis because of progressive compositional changes of inputs and concurrent redistributive processes (Examples: UK marine waters; Read & Blackman, 1980; Law, 1981; Fileman & Law, 1988; North Sea Task Force, 1993; Law *et al.*, 1994).
Visible oil slicks.	Sightings of oil slicks from ships operating in estuaries, coastal waters and the open sea.	Observations limited by shallow viewing angles, weather conditions, daylight hours, attitudes of crews and rates of dispersive processes (Hornstein, 1973; Oostam, 1980; Sen Gupta & Kureishy, 1981).

Table A4.1: A framework for determining vessel-source oil inputs to the waters around the British Isles.

Physical form of oil	Measurement method & application	Limitations
Oil slicks.	Observations and other measurements during dedicated surveillance or other overflights, usually in the vicinity of major shipping routes.	Reports of visible sightings more consistent and accurate than observations from ships, but contain a high proportion of false sightings, thereby requiring confirmation. Routine aerial surveillance patrols equipped with remote sensing techniques more successful in detecting illegal discharges from surface oil slicks (Examples: UK waters; National Audit Office, 1991; North Sea; Andersen & Niilonen, 1995).
Visible oil slicks or films on water surface and oil residues on shorelines.	Confirmed or substantiated observations by trained personnel engaged in counter-pollution and source identification operations in tidal rivers, ports or harbours and open coastline.	Sources, circumstances and volumes of discharges often identified in ports but minor incidents may not be identified or reported. Reliability of shoreline observations may be dependent upon observer's judgement, wet versus dry conditions, type of oil and sediment colour (Owens, 1987).
Oil residues on shorelines and on the feathers of seabirds.	Presence of apparent oil residues or oil covered seabirds on beach faces during occasional or systematic observations that often undertaken by volunteers.	Accuracy and validity of observations often related to searching efficiency and other factors such as size of sampling unit, weather conditions and general experience of volunteers (Examples: UK shores: Stowe & Underwood, 1984; Rees & Pond, 1993; 1994).

Table A4.1 continued.

ADVISORY COMMITTEE ON PROTECTION OF THE SEA - OIL POLLUTION SURVEY

REPORT OF OIL POLLUTION INCIDENT OR OF CHRONIC OIL POLLUTION

1.NAME OF REPORTING ORGANISATION OR AGENCY:

FOR ACOPS USE ONLY
Questionnaire No. . . . . .
Incident No. . . . . .

2. Does this report describe:

1. A pollution incident	
2. Chronic pollution	
3. Threat of pollution	
4. No pollution	

3. When did pollution occur:-
(please either insert exact dates or mark the months)

Year 19

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

5.Zone polluted;

1. Open sea beyond territorial limits. Distance from coast (if known). . . . . miles	
2. Tidal river or estuary	
3. Bay or nearshore waters	
4. Beach or shore	
5. Port or harbour	
6. Other.	
0. Not known	

4. Position or location of oil pollution
. . . . . .
Lat./Long. Or Nat. grid coordinates if known
. . . . . .

6. Length of coast affected. . . . . .miles
OR from:
to:
OR not known

7. Length of time pollution remained:
At sea. . . . . .days/weeks
On shore. . . . . days/weeks
Not known

9.From whom did you hear about the oil pollution:-

1. Aircraft - civil/military	
2. H.M. Coastguard	
3. Local/harbour authority	
4. Fishery officer/fishermen	
5. Vessel at sea	
6. Local wildlife group or conservation society	
7. Individual or group of tourists/sightseers	
8. Oiled birds washed ashore	
9. Department of Trade	
10.Oil Company	
11.Other.	
12.News Media	

8. Intensity or degree of pollution:

On Water		On Shore	
1. Oily film, scattered blobs or lumps		Oily film, scattered blobs or lumps	
2. Slick up to 3 metres (10') wide		Oily band up to 1 metre wide	
3. Several slicks as above; or big slick 100 metres (300') extent		Band of oil several metres wide, or large patches all over the shore	
4. Large slick, 100 metres to 1.6 km (1 mile) in extent		Very thick band of oil; exposed shore 50% to 80% covered	
5. Very large slick over one mile in extent		Shore totally covered with oil	
0. Not known		Not known	

10. Source of pollution

10. Attributable: source identified	
20. Unattributable: source unidentified	

1. Coastal tanker/VLCC/ULCC	
2. Non-tanker ship	
3. Disturbance of wreck	

4. Offshore oil platform/rig	
5. Pipeline	
6. Land terminal	
7. Industrial premises	
8. Sewer or outfall	
9. Other	
10. Not known	

11. Name of vessel, platform, or other source (if applicable)

Not known ☐

Table A4.2: Questionnaire employed in the ACOPS annual survey of oil pollution in the waters around the United Kingdom.

12.Operation in progress/circumstances of spill

1. Loading cargo	
2. Discharging cargo	
3. Taking on ballast	
4. Discharging ballast	
5. Bunkering	
6. Pumping bilges	
7. Cleaning tanks	
8. Other intentional/deliberate discharge	
9. Collision	
10.Stranding/grounding	
11.Explosion	
0. Not known	

13.Cause of oil spillage

1. Failure or defect in hull or tank	
2. Hose failure	
3. Loading arm failure	
4. Valve left open	
5. Leaking valve	
6. Other equipment/material failure	
7. Poor design of equipment	
8. Improper/ineffective procedure	
9. Lack of supervision	
10.Operator inattention	
11.Lack of communication	
12.Other human element/error	
0. Not known	

14. Type of oil

1. Fresh crude oil	
2. Viscous soft lumps	
3. Weathered hard lumps	
4. Chocolate mousse	
5. Fuel or bunker oil	
6. Other petroleum spirit	
7. Vegetable/animal/edible oil	
8. Presently being identified	
0. Not known	

15. Amount of oil spilled

Insert actual/estimated/suspected* amount

where known. . . . . .
(specify units)

*delete as appropriate. Not known ☐

17. Zone or location cleaned

1. Water surface	
2. Sea shore, strand	
3. Sea-wall	
4. Harbour, dock	
5. Other.	
0. Not known	

18. Clean-up methods used

1. No cleaning action taken	
2. Manual or mechanical pick-up	
3. Physical/chemical containment	
4. Recovery of oil on water	
5. Hosing, washing with water	
6. Use of dispersants*	
7. Sinking agents used	
8. Oil burned at sea/ashore	
9. Other methods.	
0. Not known	

*Insert actual amount of dispersant

used if known. . . . . litres/gallons

19. Fate of oil

1. Natural breakdown	
2. Burned at sea/ashore	
3. Dispersed or sunk at sea	
4. Dumped or buried ashore	
5. Resold or rerefined	
6. Other.	
7. Not known	

16. Extent of clean-up operation or of natural dispersion of oil

1. Complete clean-up undertaken; area now free of oil	
2. Partial clean-up: remainder of oil removed completely by natural agencies	
3. Partial clean-up; some oil still remaining	
4. No clean-up action: oil completely removed by natural agencies	
5. No clean-up action: some oil still remaining	

Table A4.2 continued.

20. Damage and detrimental effects

1. None perceived or reported	
2. Tourism/amenities affected	
3. Fish fisheries damaged	
4. Marine/seashore plants damaged	
5. Seabirds oiled/killed	
6. Other marine animals affected	
7. Not yet determined	
0. Not known	

22. Rehabilitation measures undertaken

1. None required or carried out	
2. Coastal amenities reinstated	
3. Fishing gear or boats made good	
4. Seabirds cleaned	
5. Compensation paid	
6. Other.	
0. Not known	

21. Effects on Wildlife

Seabirds	Oiled Dead	Oiled Alive	Destroyed	Cleaned	Released
1. Auks 2. Seaduck 3. Other					
Total Numbers					

Damage to seashore plants and animals

4. No damage	
5. Slight; animals 'knocked out' but few deaths	
6. Medium; death of a number of species in a small area	
7. Severe; death of a number of species over a large area	

8. Biologically sensitive areas affected	
9. Habitat adversely affected by clean-up operations (details if known can be added under question 31)	

23. Other action taken

1. No other action taken	
2. Oil slick tracked/position noted	
3. Sample of oil taken/analysed	
4. Warning/protest issued	
5. Offending vessel/install. Inspected	
6. Prosecution initiated	
7. Verdict: guilty/not guilty	
8. Amount of fine £.	
9. Costs awarded £.	
10. Other action.	
0. Not known	

24. Approximate man-hours spent in clean-up/ rehabilitation if known. . . . . . .

25. Approximate direct or identifiable costs of:

1. Clean-up action	£. . . . .
2. Rehabilitation	£. . . . .
3. Other action	£. . . . .
4. Materials consumed	£. . . . .
0. Not known	

26. Indirect additional costs such as time of employees engaged in clean-up/supervision/reporting etc. £. . . . . . .

27. Approximate gross total cost incurred by

1. Your own organisation £. . . . . . .
2. Others, if known (specify). . . . . . **£.** . . . . . .

Table A4.2 continued

28. Costs so far recovered from. . . . . (specify source) £. . . . .   Costs still to be recovered from. . . . . (specify source) £. . . . .
29. Nett expenditure estimated for this incident £. . . . .
30. Constraints, limitations or difficulties faced in clean-up or other action
Your comments above will be kept confidential if you so indicate ☐
31. Any other comments or additional points you wish to make
32. This report completed by: Date. . . . . 19. . . . .   Name: Position: Address: Telephone number   Telex:

Table A4.2 continued.

Reporting organisations	Number of questionnaires returned	Information sources
Animal welfare organisations	20	Questionnaires completed by coastal local inspectors for the Royal Society for the Prevention of Cruelty to Animals in England & Wales and each of 3 Scottish Societies for the Prevention of Cruelty to Animals concerning incidents involving oiled seabirds.
Association of Sea Fisheries Committees	9	Each of 13 local Sea Fishery Committees in England & Wales describing sightings of oil at sea and vessel-casualties.
British Ports Association	172	Harbourmasters representing 116 Port & Harbour Authorities in England, Wales, Scotland & Northern Ireland including all major oil terminals.
Coastguard Agency	213	Questionnaires completed by the Marine Pollution Control Unit from all confirmed reports of oil pollution received by HM Coastguard from other sources, primarily aircraft and ship sightings of oil slicks in the open sea.
Department of Trade & Industry	144	Questionnaires completed centrally from reports of accidental oil spillages during offshore oil & gas industry operations on the United Kingdom Continental Shelf (UKCS). Supplementary information from dedicated airborne surveillance flights organised by the MPCU.

Table A4.3: Reporting organisations voluntarily contributing information to the 1995 ACOPS annual oil pollution survey. (From: Dixon & Dixon, 1996).

Reporting organisations	Number of questionnaires returned	Information sources
Department of the Environment for Northern Ireland.	1	Questionnaires completed centrally from oil pollution incidents reported in all coastal districts and the tidal stretches of rivers.
Local Authority Associations (Associations' of County Councils, District Councils & Metropolitan Authorities and the Convention of Scottish Local Authorities).	276	Designated oil pollution officers representing 190 coastal county, district and unitary authorities in all parts of England, Wales and Scotland.
National Rivers Authority (Environment Agency from 1 April 1996)	35	Each of 8 coastal regions in England & Wales submitting details of substantiated category I (major incidents) & category II(significant incidents) involving oil spills or discharges to coastal waters and the tidal stretches of rivers.
Scottish River Purification Boards (Scottish Environment Protection Agency from 1 April 1996)	67	Questionnaires completed by each of 7 River Purification Boards describing substantiated incidents in the tidal stretches of rivers, estuaries, port areas and nearshore waters.

Table A4.3 continued.

Year	1993		1994		1995		1993-1995	
Source	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Tanker vessels	34	5.03	28	5.19	23	3.93	85	4.72
Other vessels	153	22.63	127	23.52	139	23.76	419	23.26
Disturbance of wrecks	1	0.15	2	0.37	3	0.51	6	0.33
Offshore oil & gas installations	183	27.07	149	27.59	145	24.59	477	26.49
Oil pipelines, terminals or jetties	11	1.63	16	2.96	19	3.25	46	2.55
Industrial premises, outfalls & other sources	41	6.07	45	8.33	46	7.86	132	7.33
Not reported	253	37.43	173	32.03	210	35.90	636	35.31
Totals	**676**	**100.00**	**540**	**100.00**	**585**	**100.00**	**1801**	**100.00**

Table A4.4: Reported sources of observed pollution, 1993-1995. (From: Dixon & Dixon, 1994; 1995; 1996).

Year	1993		1994		1995		1993-1995	
Zone	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Open sea	377	55.77	280	51.85	303	51.79	960	53.30
Bay or nearshore waters	22	3.25	29	5.37	31	5.30	82	4.55
Tidal stretches of rivers & estuaries	20	2.96	26	4.81	45	7.69	91	5.05
Beach or shore	64	9.47	49	9.07	52	8.89	165	9.16
Ports or harbours	193	28.85	156	28.89	154	26.32	503	27.93
Totals	**676**	**100.00**	**540**	**100.00**	**585**	**100.00**	**1801**	**100.00**

Table A4.5: Distribution of reported oil pollution by marine environmental zones, 1993-1995. (From: Dixon & Dixon, 1994; 1995; 1996).

Year	1993		1994		1995		1993-1995	
Type or physical form	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
Fresh crude oil	193	27.89	160	29.63	157	26.83	510	28.07
Lumps of oil & "chocolate mousse"	32	4.62	27	5.00	21	3.59	80	4.40
Fuel or bunker oils	211	30.49	168	31.11	231	39.49	610	33.47
Other refined products	111	16.04	59	10.93	58	9.91	228	12.55
Not reported	145	20.95	126	23.33	118	20.17	389	21.40
Totals	**692**	**100.00**	**540**	**100.00**	**585**	**100.00**	**1817**	**100.00**

Table A4.6: Types and physical forms of oil reported, 1993-1995. (From: Dixon & Dixon, 1994; 1995; 1996).

Vessel type	Number of incidents reported	Total estimated volume of oil lost with vessels or spilt at sea
Fishing vessels including fish factory ships	32	1,400[a] tonnes of fuel and lubricating oils.
Oil tankers	2	86,100[b] tonnes crude, heavy fuel, gas & lubrication oils
Other types of vessels	7	270 tonnes of fuel, lubrication & gas oils.

[a] Excluding 695 tonnes of fuel oil removed from the wrecks of the *Borodinskoye Polye* and *Pionersk* which ran aground on Shetland on 18 November 1993 & 31 October 1994 respectively

[b] Excluding 104 tonnes of oil removed from the wreck of the *Braer* which ran aground on Shetland on 5 January 1993.

Most frequently reported casualty-types including capsizings, collisions, fires & groundings.

Table A4.7: Summary of larger incidents (2 tonnes or more) caused by vessel-casualties, 1993-1995. (From: Dixon & Dixon, 1994; 1995; 1996).

Year	1993		1994		1995		1993-1995	
Volume (tonnes)	**Total**	**%**	**Total**	**%**	**Total**	**%**	**Total**	**%**
< 0.39	276	40.83	264	48.89	363	62.05	903	50.14
0.40 - 1.0	35	5.18	34	6.30	49	8.38	118	6.55
1.1 - 50	62	9.17	63	11.67	45	7.69	170	9.44
>50	2	0.30	2	0.37	1	0.17	5	0.28
Not reported	301	44.53	177	32.78	127	21.71	605	33.59
Totals	**676**	**100.00**	**540**	**100.00**	**585**	**100.00**	**1801**	**100.00**

Table A4.8: Reported estimates of the volumes of observed pollution, 1993-1995. (From: Dixon & Dixon, 1994; 1995; 1996).

Prosecutions brought by competent authorities in the United Kingdom.

	British vessels	Foreign vessels	Total
Convictions	17	19	36
Total fines imposed	£16,150	£33,900	£50,050

Prosecutions brought under the Prevention of Oil Pollution Act,1971; Control of Pollution Act,1974; Merchant Shipping (Prevention of Oil Pollution) Regulations, 1983; Prevention of Oil Pollution Act,1986; Environmental Protection Act,1990.

Actions taken by flag state administrations following referrals by the Department of Transport.

(i) Cases referred to flag state administrations 1993-1995: 33 in total.

(ii) Referrals closed 1993-95: 3 cases resulting in convictions by flag states, but no details of fines imposed; 3 cases dismissed through lack of evidence; 3 cases lost.

Table A4.9: Summary of prosecutions brought by competent authorities following alleged oil pollution offences by ships in UK waters and actions taken by flag state administrations following referrals by the Department of Transport,1993-1995. (From: Dixon & Dixon, 1994; 1995; 1996).

Name of vessel	Date	Type of incident	Nature of incident	Area affected
Germania	January 1972	Coaster caught fire and sank.	Drums of dangerous chemicals drifted 160 km ashore.	Cornwall (Anon., 1972c).
Aeolian Sky	November 1979	General cargo vessel sank following collision.	Many unmarked packages washed ashore.	Southern England (Dixon & Dixon, 1981a).
Craigantlet	February 1982	Container vessel ran aground.	Inaccurate identification of contents pressure vessel tanks.	Portamaggie Bay, Scotland (Dixon, 1992).
European Gateway	December 1982	Ro-ro ferry capsized following collision.	Dangerous goods cargo recovered over a large area.	Kent coast and German Bight (Dixon, 1992).
Dana Optima	January 1984	Ro-ro ferry lost deck cargo.	Loss of 80 drums (16 tonnes) of concentrated herbicide dinoseb.	Area to the north of Dogger Bank (Stamp, 1988).
Mount Louis	August 1984	Ro-ro vessel capsized following collision.	30 containers of uranium hexafluoride recovered.	Empty container stranded on a Norfolk beach (Dixon & Dixon, 1985).

Table A5.1: Summary of major incidents involving packaged dangerous/harmful goods lost from vessels operating in the waters around the British Isles.

Name of vessel	Date	Type of incident	Nature of incident	Area affected
Forum Hope	October 1984	General cargo vessel lost deck cargo.	Unmarked and leaking packages washed ashore without warning.	Dorset coastline (Dixon & Dixon, 1986).
Filia Sea	March 1987	General cargo vessel lost cargo.	Packages stranded on beach without warning.	East Anglia (Dixon, 1992).
Ardlough	September 1988	General cargo vessel sank.	Leaking tank containers washed ashore.	Cumbria and Lancashire (Dixon, 1989a).
Wessertal	October 1988	Ro-ro ferry lost deck cargo.	Leaking 24,000 l tank container adrift for 4 weeks.	Southern North Sea (Dixon, 1992).
Perintis	March 1989	General cargo vessel capsized and sank.	Recovery operation failed to locate some of pesticide cargo.	English Channel (Dixon, 1989c).
Muree	October 1989	General cargo vessel sank.	Unmarked packages washed ashore over many weeks.	South Wales to Norfolk (Anon., 1990b).

Table A5.1 continued.

Name of vessel	Date	Type of incident	Nature of incident	Area affected
Fathulkhair	February 1990	Freighter lost deck cargo.	6 canisters of potassium cyanide washed ashore without warning.	Kent and Sussex (Dixon, 1992).
Nordic Pride	May 1991	Ro-ro ferry lost deck cargo.	2 "hukta trucks" washed ashore in a leaking condition causing an evacuation of the local population.	Norfolk coastline (Norfolk Standing Emergencies Working Group, 1991).
Sherbro	December 1993	Containership lost 88 box containers overboard.	Search & recovery operation mounted for 43 t of dangerous cargo including nitrocellulose, flammable liquids and seed treatment *Apron plus.*	Seine Bay to Germany over a 3 month interval (Anon., 1994).
Tokio Express	February 1997	Containership lost 62 box containers overboard.	800 glass phials of methylmethacrylate missing, some recovered ashore.	Cornwall (Speares, 1997).

Table A5.1 continued.

ACOPS

ADVISORY COMMITTEE ON PROTECTION OF THE SEA

Survey of packaged dangerous goods and other hazardous items or substances found in UK waters and on beaches

1 OCTOBER 1991 - 30 SEPTEMBER 1992

GUIDANCE NOTES

The survey is being undertaken with the assistance of The Tidy Britain Group to discover the types and quantities of hazardous substances or items recovered at sea and on beaches, to ascertain any problems encountered by public agencies in handling and safely disposing of these materials, and to help assess the associated risks to beach users and those engaged in the exploitation of marine resources.

It is organised in 2 parts, in which respondents are requested to complete and return separate questionnaires at 6 monthly intervals;
from 1 October 1991 to 31 March 1992 (returned to ACOPS by 30 April 1992),
and 1 April 1992 to 30 September 1992 (returned to ACOPS by 30 April 1992).

You will receive another questionnaire for the second part of the survey during March 1992.

In order to obtain comprehensive results there may well be several respondents within the same district or county.

In the event of any difficulties, or if further information is required, please contact the appropriate regional advisor:-

SCOTLAND	Mr Tim Dixon. Stirling District Council (0786) 50403 Ext. 152,
WALES	Mr J. Wardley-Smith, O.B.E. ACOPS (0792) 390451,
ENGLAND	Mr Trevor Dixon ACOPS (0494) 441833, or the ACOPS office (071) 4990704

This questionnaire is in 5 sections. Please complete each section as appropriate.

Section 1: Details of respondent
Section 2: Positively identified packaged dangerous goods (e.g. chemical drums)
Section 3: Details of suspect packages later found to contain harmless substances
Section 4: Reports concerning other hazardous substances or items such as clinical wastes or munitions.
Section 5: Any additional or supporting information.

SECTION 1: DETAILS OF RESPONDENT

Name of respondent .....

Name, address and telephone number of reporting authority

If you have no incidents to report, enter a tick in the box and return the questionnaire to

The Advisory Committee on Protection of the Sea,
57 Duke Street, Grosvenor Square,
LONDON W1M 5DH

Telephone : 071-499-0704
Fax : 071-493-3092

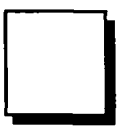

Table A5.2: Questionnaire employed in the 1991/1992 survey of minor chemical incidents around the shores of the United Kingdom. (From: Dixon, 1992).

SECTION 2: DETAILS OF PACKAGES CONTAINING DANGEROUS OR HAZARDOUS SUBSTANCES

Guidance Notes

2: **Geographical location** Use place names and map references, Decca or geo-coordinates.
4: **Substance identification** Identify substances by chemical formulae, trade names, U.N. Numbers and nature of hazard.
5: **Package markings and labels** Record substance names and the nature of the hazard, if visible on packages
6: **U.N. packaging Code** Enter details of embossed or other markings
8: **Origin** If known, state source. Add further information in Section 5
10: **Advance warning** Please indicate whether you were given advance warning of an incident.
11: **Damage** Please provide details of any damage or personal injuries resulting from an incident. Additional information can be given in Section 5.

1:DATE FOUND OR REPORTED	2:GEOGRAPHICAL LOCATION	3:TYPES, CAPACITY AND NUMBER OF PACKAGES	4:CONTENTS OF EACH PACKAGE	5:WERE SUBSTANCES AND HAZARD WARNING LABELS VISIBLE AND LEGIBLE YES/NO
Example 1/10/91	*DOVER, KENT 51 7N 1.19E*	*1x 23 litre plastic carboy*	*Perchloric acid U.N. No. 1873*	*YES Perchloric acid Corrosive*

6:U.N. PACKAGING SPECIFICATION	7:EVIDENCE OF LEAKAGE YES/NO	8:ORIGIN	9:METHOD OF DISPOSAL	10:ADVANCE WARNING YES/NO	11:EVIDENCE OF DAMAGE OR PERSONAL INJURY
(UN) *3H1/Y19/200/89 B/86220/Ttc*	*No*	*Lost cargo from ship*	*Incineration*	*No*	*None*

(Continue on a separate sheet if necessary)

Table A5.2 continued.

SECTION 3: ENTER INFORMATION OF ANY SUSPECTED HAZARDOUS PACKAGES WHICH WERE LATER FOUND TO BE EMPTY OR CONTAIN HARMLESS SUBSTANCES

Guidance Notes

2: **Geographical location** Use place names and map references, Decca or geo-coordinates.
4: **Substance identification** Identify substances by chemical formulae, trade names, U.N. Numbers and nature of hazard.
5: **Package markings and labels** Record substance names and the nature of the hazard, if visible on packages
6: **U.N. packaging Code** Enter details of embossed or other markings
8: **Origin** If known, state source. Add further information in Section 5
10: **Advancé warning** Please indicate whether you were given advance warning of an incident.
11: **Damage** Please provide details of any damage or personal injuries resulting from an incident. Additional information can be given in Section 5.

1:DATE FOUND OR REPORTED	2:GEOGRAPHICAL LOCATION	3:TYPES, CAPACITY AND NUMBER OF PACKAGES	4:CONTENTS OF EACH PACKAGE	5:WERE SUBSTANCES AND HAZARD WARNING LABELS VISIBLE AND LEGIBLE YES/NO
Example 1/10/91	*DOVER, KENT O.S. SHEET 179 321041*	*1x 205 litre metal drum*	*Seawater*	*No*

6:U.N. PACKAGING SPECIFICATION	7:EVIDENCE OF LEAKAGE YES/NO	8:ORIGIN	9:METHOD OF DISPOSAL	10:ADVANCE WARNING YES/NO	11:EVIDENCE OF DAMAGE OR PERSONAL INJURY
Absent	*No*	*Land-based*	*Landfill*	*NOT Applicable*	*None*

(Continue on a separate sheet if necessary)

Table A5.2 continued.

SECTION 4: OTHER SUBSTANCES OR ITEMS

Record details of any other potentially dangerous or hazardous substances or items, including munitions, pyrotechnics (distress flares etc.), pharmaceutical drugs and clinical wastes.

DATE	LOCATION	SUBSTANCE OR ITEM	ORIGIN	METHOD OF DISPOSAL	EVIDENCE OF DAMAGE OR PERSONAL INJURY
Example 1/10/91	*DOVER KENT*	*3 syringes with needles*	*Not known*	*Incineration*	*Bather received treatment and tests*

(Continue on a separate sheet if necessary)

SECTION 5: ADDITIONAL INFORMATION

Please add any supporting information: legal proceedings; difficulties experienced during clearance and disposal operations and estimated expenditure; health risks to those engaged in clearance operations and local populations; details of lost cargo (e.g. name of ship, nationality, voyage details, name of shipper).
Add any relevant photographs, press cuttings or other published material.

(Continue on a separate sheet if necessary)

Please return to The Advisory Committee on Protection of the Sea,
57 Duke Street, Grosvenor Square,
LONDON W1M 5DH FAX NUMBER 071-493-3092

Before 30 April (1992) for the period 1 October 1991 - 31 March 1992,
and before 14 October (1992) for the period 1 April 1992 - 30 September 1992

Table A5.2 continued.

Organisation	Questionnaire Distribution
Countryside Council for Wales	Each of 15 wardens and rangers at coastal sites
[a]County Councils in England & Wales	Emergency Planning Departments at 31 coastal County Councils
[a]District Councils in England & Wales	Environmental Health or Engineers Departments of 115 coastal authorities
[a]District Councils in Northern Ireland	Environmental Health Departments of 12 coastal authorities
English Nature	Each of 14 coastal site reserve managers
Heritage Coastal Forum	Each of 44 Heritage Coast offices
[a]Her Majesty's Coastguard	Each of 27 regional centres
[a]Metropolitan Districts, Fire Brigade and Civil Defence Authorities	Chief Executive of each organisation.
National Federation of Fishermen's Organisations	Each of 60 Associations in England & Wales
National Rivers Authority	Each of 10 coastal regional offices

[a] Primary data sources

Table A5.3: List of organisations contributing information to the 1991/1992 survey of chemical packages and other hazardous materials recovered on UK beaches. (From: Dixon, 1992).

Organisation	Questionnaire Distribution
National Trust for Scotland	Each of 16 coastal centres
[a]Royal Navy Clearance Diving Units	Each of 3 regional centres
Scottish Fisherman's Federation	Each of 7 regional associations
Scottish Natural Heritage	Wardens in coastal areas
Scottish Office: Agriculture & Fisheries	Each of 19 Sea Fisheries Inspectorate Offices
[a]Scottish Regional & District Councils	Emergency Planning or Environmental Health Departments of 49 authorities
Scottish River Purification Boards	Each of 7 Boards
Sea Fisheries Committees	Each of 12 regional committees in England & Wales
The National Trust	Each of 12 coastal centres in England,Wales and Northern Ireland.
United Kingdom Ports	Representative sample of 10 ports selected in consultation with the British Ports Association
Water Businesses in England & Wales	Sample of 6 businesses in coastal regions

[a] Primary data sources

Table A5.3 continued

Name of vessel	Date	Major difficulties encountered during search and recovery operations
Germania	January 1972	Emergency response teams unprepared for the hazardous nature of the contents of drums washed ashore (Anon., 1972b; 1972c).
Aeolian Sky	November 1979	Dangerous goods manifest listed only secondary or transit packaging units; 50% of 3,500 packagings recovered on beaches had lost their labels following immersion in the sea; 32 canisters of arsenic trichloride recovered on beaches lost from the deck cargo of another vessel (Dixon & Dixon, 1981a).
Craigantlet	February 1982	Contents of 22,000 l tank identified as methyl sulphate salts on ship's manifest but subsequently identified as postassium methyl sulphate compound; damaged and inaccessible venting valves to pressurised gas tanks; local authorities unable to recover costs incurred in clearance operations from ship & cargo owners, central Government or other interested parties (Murray, 1982).
European Gateway	December 1982	Packaged chemical cargo units recovered over a large geographical area including the Kent coast and the shores of the German Bight (Dixon & Dixon, 1985).
Dana Optima	January 1984	Exact location where cargo lost not known; 3 day delay in identifying dangerous/harmful goods lost; most of the herbicide drums recovered in the nets of fishing vessels and during the search and recovery operations were found to be in a leaking condition (Stamp, 1988).

Table A5.4: Difficulties encountered by the authorities when responding to major incidents involving losses of chemical cargoes from ships operating in the waters around the British Isles.

Name of vessel	Date	Major difficulties encountered during search and recovery operations
Mount Louis	August 1984	Delay of several days in identifying dangerous cargo; authorities claimed that all uranium hexafluoride canisters recovered (Peet, 1988); empty canisters washed ashore without warning up to 11 months later (Dixon, 1992).
Forum Hope	October 1984	Loss of deck cargo comprising 2,400 drums not reported by the Master until vessel reached destination a week later and information not relayed to local authorities until a month later; substances listed on dangerous goods manifest did not correspond fully with materials recovered ashore; 90% of recovered packages unmarked (Dixon & Dixon, 1986).
Filia Sea	March 1987	Master of the vessel unable to indicate total number of packages lost, as it was not known how many were stowed above and below deck until vessel reached desination in China; Suffolk County Council unable to recover costs incurred in recovery operation (Stansfield, *pers. comm.)*
Ardlough	September 1988	Hazard warning and substance markings became detached with outer cladding of 2 tank containers filled with dangerous substances within 3 days of immersion in the sea; controlled spillage of 16,000 l of ethyl acetate from leaking tank container required to avoid a risk of serious explosion on Blackpool beach (Dixon, 1989a).
Wessertal	October 1988	Authorities unable to recover floating tank container filled with 24,000 l of hexamethylenediamine solution because of toxic fumes (Anon., 1988).
Perintis	March 1989	Box container filled 5.8 t of lindane (gamma-HCH) packaged in polythene bags and fibreboard drums sank without trace when being towed to port at Cherbourg; precautionary controls on fishing required; low level monitoring of surface water samples carried out to detect elevated levels of lindane (Dixon, 1989c; Law & Allchin, 1994).

Table A5.4 continued

Name of vessel	Date	Major difficulties encountered during search and recovery operations
Muree	October 1989	Cargo included at least 4 box containers filled with chemicals; many chemical packages recovered from beaches up to 6 weeks later. Authorities surprised at the extent to which some packages had drifted before coming ashore (Anon., 1990b).
Fathulkhair	February 1990	Some of dangerous goods recovered without required package markings; flag state of vessel not a party to the 1974 SOLAS Convention (De Leon, *pers. comm.).*
Nordic Pride	May 1991	Initial information imprecise regarding size of containers and location; delay in obtaining required chemical expertise; no statutory duty on the police to enforce evacuation instructions; difficulties encountered in identifying ethyl acrylate as labels became detached from tanks with outer cladding, leaving only tank shells (Norfolk Standing Emergencies Working Group, 1991).
Sherbro	December 1993	2 t of pesticide in loose sachets collected from the shores of France, Belgium and the Netherlands (Law, 1994).
Tokio Express	February 1977	Box container sank under tow releasing 100,000 cigarette lighters, which were later removed from amenity beaches in Cornwall (Corkill, 1997).

Table A5.4 continued

Class[a]	U.N. No.	Substance	Formula	Packaging Group	Packages	No. of packages with hazard warnings	Comments
Class 2 gases							
2(2.1)	1011	Butane	-	-	Three high pressure cylinders	-	-
2(2.1)	1040	Ethylene oxide	C_2H_4O	-	One 5 l container	1	Subsidiary risk, poison gas. Containing more than 0.2% nitrogen
2(2.2)	1013	Carbon Dioxide	CO_2	-	Two high pressure cylinders	-	-
2(2.2)	1028	Dichlorodifluoromethane	CF_2Cl_2	-	One 25 l plastics container	1	-

[a] Class 2 Gases: compressed, liquified or dissolved under pressure. Class 2.1 - Inflammable gases. Class 2.2 - Non-inflammable gases

Table A5.5: The types and quantities of Class 2 packaged dangerous goods reported during the 1983/1984 survey of minor chemical incidents. (From: Dixon & Dixon, 1985).

Class[a]	U.N. No.	Substance	Formula	Packaging Group	Packages	No. of packages with hazard warnings	Comments
Class 3 Flammable Liquids							
3.1	1089	Acetaldehyde	CH_3CHO	I	One plastics container	-	-
3.1	1133	Adhesive (inflammable)	-	II	One metal container	-	-
3.1	1155	Ether	$(C_2H_5)_2O$	I	Three 205 l drums One 227 l drum	-	One drum with substance identification marking only
3.2	1148	Diacetone alcohol	$CH_3COCH_2C(CH_3)OH$	II	One 205 l drum	-	Part substance identification marking only
3.2	1230	Methanol	CH_3OH	II	One 23 l container	1	Container leaking Subsidiary risk, poison
3.2	1282	Pyridine	$N(CH)_4CH$	II	Three 205 l drums	-	[b] Subsidiary risk, poison
3.3	1134	Chlorobenzene	C_6H_5Cl	II	One 205 l drum	-	-
3.3	1198	Formaldehyde solution	HCHO	II	One 5 l container One 23 l drum One 205 l drum	-	One drum with substance identification label only
3(1,2 or3)	1267	Petroleum crude oil	-	II	Two 5 l containers	-	-

[a] Class 3.1 Low flashpoint group, flashpoint below -18°C (0°F). Class 3.2 Intermediate flashpoint group, flashpoint -18°C (0°F) up to, but not including 23°C (73°F). Class 3.3 High flashpoint group of 23°C (73°F) up to and including 61°C (141°F).

[b] Believed to originate from the wreck of the *European Gateway*.

Table A5.6: The types and quantities of Class 3 packaged dangerous goods reported during the 1983/1984 survey of minor chemical incidents. (From: Dixon & Dixon, 1985).

Class[a]	U.N. No.	Substance	Formula	Packaging Group	Packages	No. of packages with hazard warnings	Comments
Class 4 Flammable Solids							
4.1	1338	Phosphorus	P	III	One plastics container	-	Amorphous
4.1	2213	Paraformaldehyde	$HO(CH_2O)_nH$	III	One plastics container	-	No hazard warning label required

[a] Class 4.1 Solids possessing the properties of being easily ignited by external sources, such as sparks or flames, and of being readily combustible, or of being liable to cause or contribute to fire through friction.

Table A5.7: The types and quantities of Class 4 packaged dangerous goods reported during the 1983/1984 survey of minor chemical incidents. (From: Dixon & Dixon, 1985).

Class[a]	U.N. No.	Substance	Formula	Packaging Group	Packages	No. of packages with hazard warnings	Comments
Class 5 Oxidising Substances							
5.1	1438	Aluminium nitrate	$Al(NO_3)3$	III	Thirty-four 1 l plastics packages Eleven 1 kg plastics packages	44	-
5.1	1449	Barium peroxide	BaO_2	II	One 2 kg container	1	Subsidiary risk, poison
5.1	1474	Magnesium nitrate	$Mg(NO_3)_2$	III	One 1.5 l receptacle	-	-
5.1	1500	Sodium nitrite	$NaNO_3$	III	Two 23 l plastics drums. One 56 l drum	3	One package containing a solution of sodium nitrite in water, another half full.
5.1	2208	Bleaching powder	$Ca(OCl)_2$	III	One plastics package	-	Calcium hypochlorite

[a] Class 5.1 - Oxidising substances (Agents). Substances which, although in themselves are not necessarily combustible, may either by yielding oxygen or by similar processes, increase the risk and intensity of fire in other materials with which they may come into contact.

Table A5.8: The types and quantities of Class 5 packaged dangerous goods reported during the 1983/1984 survey of minor chemical incidents. (From: Dixon & Dixon, 1985).

Class[a]	U.N. No.	Substance	Formula	Packaging Group	Packages	No. of packages with hazard warnings	Comments
Class 6 Poisonous Substances							
6.1	1691	Dichlorobenzene	$C_6H_4Cl_2$	III	One 5 l drum	1	-
6.1	1593	Methylene chloride	CH_2Cl_2	III	One 1 l metal container	-	With unidentified resin. When involved in a fire may evolve extremely toxic fumes (phosgene)
6.1	1625	Mercuric nitrate	$Hg(NO_3)_2$	II	One bottle	not known	-
6.1	1671	Phenol	-	II	One metal canister	-	-
6.1	1738	Benzyl chloride	$C_6H_5CH_2Cl$	II	One 9 l package	1	Subsidiary risk, corrosive
6.1	2020	Pentachlorophenol	-	III	One 2 kg package	1	-
6.1	2489	Diphenylmethane-4,4′ Diisocyanate	-	III	One 2 l container	1	-
6.1	2505	Ammonium fluoride	NH_4F	III	One 0.5 l receptacle	-	-

[a] Class 6.1 Poisonous (Toxic) Substances. Substances liable either to cause death or serious injury or harm to human health if swallowed, or inhaled, or by skin contact.

Table A5.9: The types and quantities of Class 6 packaged dangerous goods reported during the 1983/1984 survey of minor chemical incidents. (From: Dixon & Dixon, 1985).

Class[a]	U.N. No.	Substance	Formula	Packaging Group	Packages	No. of packages with hazard warnings	Comments
Class 8 Corrosives							
8	1604	Ethylenediamine	$NH_2CH_2CH_2NH_2$	II	One 2 l receptacle. One bottle	2	Subsidiary risk, inflammable liquid
8	1733	Antimony trichloride	$SbCl_3$	II	One 1 kg package	-	-
8	1789	Hydrochloric acid solution	HCl	II	Two 15 l plastics containers. Two 20 l plastic containers. Two 30 l plastics drums	3	-
8	1791	Sodium hypochlorite solution	-	II	One 3 l plastics package. One plastics receptacle	1	With more than 5% available chlorine
8	1802	Perchloric acid	$HClO_4$	II	One 23 l plastics carboy	1	Subsidiary risk, oxidizing agent. Assumed not exceeding 50% weight of acid. Package part empty
8	1805	Phosphoric acid	H_3PO_4	III	One 23 l plastics receptacle	-	-
8	1814	Potassium hydroxide solution	KOH	II	Two plastics containers	-	-

[a] Class 8 Corrosives. Substances which are solids or liquids possessing, in their original state, the common property of being able, more or less severely, to damage living tissue.

Table A5.10: The types and quantities of Class 8 packaged dangerous goods reported during the 1983/1984 survey of minor chemical incidents. (From: Dixon & Dixon, 1985).

Class[a]	U.N. No.	Substance	Formula	Packaging Group	Packages	No. of packages with hazard warnings	Comments
Class 8 Corrosives							
8	1824	Sodium hydroxide solution	NaOH	II	One plastics container. One 23 l plastics drum	1	One package leaking
8	1903	Corrosive disinfectant	-	II	One metal cylinder	-	Liquid
8	2030	Hydrazine (aqueous solution)	$H_2N.NH_2$	II	Two plastics receptacles. Two 25 l plastics drums	1	Assumed not more than 64% by weight of hydrazine, one package part empty. Subsidiary risk poison
8	2218	Acrylic acid (inhibited)	H_2C:CHOOH	II	One 23 l drum	1	Subsidiary risk, inflammable liquid
8	2789	Acetic acid, glacial	CH_3COOH	II	Six glass phials. One 25 l plastics receptacle. One 36 l plastics drum	8	One container half-full. Six phials recovered in a single box. Subsidiary risk. Inflammable liquid
8	2796	Sulphuric acid	H_2SO_4	II	One canister. Nine bottles. One 45% plastics drum	1 (remainder not known)	Assumed not more than 51% acid
(In addition there were 2 reports of highly corrosive liquid contained in 23 l drums)							

[a] Class 8 Corrosives. Substances which are solids or liquids possessing, in their original state, the common property of being able, more or less severely, to damage living tissue.

Table A5.10 continued.

UN Number	Substance	Formula	Packaging Group	Packages	Markings	Comments
Class 2.2: Liquefied Gases						
1013	Carbon Dioxide	CO_2	-	1 x 9 kg cylinder	Substance & hazard	Non-flammable compressed gas
1066	Nitrogen	N_2	-	1 x 9 kg cylinder	Substance & hazard	Non-flammable compressed gas
Class 3.2: Flammable Liquids (Intermediate Flashpoint Group)						
1230	Methyl alcohol	CH_3OH	II	1 x 227 g tin	Hazard only	Subsidiary risk poison
1230	Methanol	CH_3OH	II	1 x 182 l metal drum	None	Contents leaking
Class 3.3: Flammable Liquids (High Flashpoint Group)						
1263	Paint thinning compound	-	III	1 x 5 l package	Substance & hazard	Marine paint thinner, Danish markings
1300	White spirit	-	III	1 x 25 l plastic container	None	May be a marine pollutant
Class 5.1: Oxidising substances/agents						
1495	Sodium chlorate	$NaClO_3$	II	1 x 2.5 l can	Not known	Sensitive to friction & liable to ignite
2014	Hydrogen peroxide	H_2O_2	II	1 x 25 l plastic container	Substance & hazard	Subsidiary risk corrosive

Table A5.11: The types and quantities of packaged dangerous/harmful goods reported during the 1991/92 survey of minor chemical incidents. (From: Dixon, 1992).

UN Number	Substance	Formula	Packaging Group	Packages	Markings	Comments
Class 6.1: Poisonous (toxic) substances						
2076	Cresols	$CH_3C_6H_4OH$	II	1 x 25 l steel drum	Substance & hazard	Package filled with a mixture of 23% Cresols with naphtha Marine pollutant
				1 x 25 l metal container	None	Marine pollutant
2831	Methylchloroform	CH_3CCl_3	III	1 x canister	Substance only	Marine pollutant
2831	1,1,1 Trichloroethane	CH_3CCl_3	III	1 x 25 l drum	Substance & hazard	Marine pollutant Harmful label required
				1 x 25 l package	Substance & hazard	Package leaking contents Marine pollutant

Table A5.11 continued.

UN Number	Substance	Formula	Packaging Group	Packages	Markings	Comments
Class 8: Corrosives						
1789	Hydrochloric acid, solutions	HCl	II	1 x 50 l package	Not known	-
				1 x 25 l drum	Substance & hazard	20% solution
				1 x 182 l drum	Substance & hazard	-
1791	Sodium hypochlorite, solutions	-	II/III	2 x 25 plastic containers	Substance & hazard	Two leaking contents. UN Packaging Specification Codes visible 1 package only
				1 x 23 l package	Substance & hazard	
				1 metal drum	Substance only	
1805	Phosphoric acid	H_3PO_4	III	1 x 25 l container	None	Package leaking contents
				2 x 5 l plastic containers	Not known & none	-
1823	Sodium hydroxide crystals	NaOH	II	1 x 23 l plastic drum	Substance & hazard	Package leaking contents, half recovered
1824	Sodium hydroxide solution	NaOH	II	1 x 227 l metal drum	None	Package leaking contents
2031	Nitric acid	HNO_3	I/II	1 x 25 l package	Not known	Other than red fuming nitric acid
2693	Sodium bisulphite solution	-	III	1 x 23 l package	Not known	Marine pollutant
				1 x package	Not known	Marine pollutant
Class 9: Miscellaneous Dangerous Substances and Articles						
2590	White asbestos	-	III	1 x package	Not known	No label required
3082	Creosote	-	III	1 x package	None	Marine pollutant

Table A5.11 continued.

Substance/Trade Name	Packages	Markings
Class 1: Explosives		
Plastic explosives	1 x 600 mm square wooden box	None
Class 3: Flammable Liquids		
Euro-Lopoten	1 x 5 l plastic container	Flammable, toxic, UN Class 3 & UN Packaging Specification Code (Belgium)
Unknown flammable liquids	1 x 2 l package 3 x 25 l containers 1 x 900 mm x 300 mm package	Not known Two with flammable labels and the other not known Flammable
Class 6: Poisonous (Toxic) Substances		
Yellow, cyanide based toxic liquid	1 x 150 x 10 mm vial	None
Unknown toxic liquid	1 x 20 l steel drum	None
Herrifex dilute weedkiller	1 x 23 l plastic drum	Toxic
Pesticide	1 x 25 l container	Not known
Class 8: Corrosives		
Houseman Cooltreat	1 x 25 l metal drum	Corrosive
Alkaline cleansers	1 x 5 l plastic containers 3 x 10 l plastic containers	Corrosive on each
Unidentified corrosive liquids	1 x 1 l plastic carboy 1 x 1 l plastic container	Corrosive on each
Unidentified corrosive substance	1 x 20 l metal drum	None
Unidentified acids	1 x 25 l plastic container 1 x 10 l plastic container	Corrosive None
Class 9: Miscellaneous Dangerous Substances and Articles		
Liquid substance	1 x 68 l drum	Marine pollutant

Table A5.12: The types and quantities of partly identified packaged dangerous/harmful goods reported during the 1991/92 survey of minor chemical incidents. (From: Dixon, 1992).

IMDG Code Packaging Group	England & Wales 1982/83[a]		United Kingdom 1991/92[b]	
	n	%	n	%
I (Great Danger)	5	4	1[c]	4
II (Medium Danger)	59	48	15[d]	54
III (Minor Danger)	58	48	12	43
Totals[e]	**122**	**100**	**28**	**100**

a From: Dixon & Dixon (1985).

b From: Dixon (1992).

c The identified substance could have been classified as Packaging Group I or II

d Included 4 substances which may have been classified as Packaging Group II or III.

e Excluded substances which had not been allocated Packaging Groups in the 1990 edition of the IMDG Code and those only partly identified (9 substances in the 1982/83 data and 24 in the 1991/92 data).

Table A5.13: Relative hazard ratings by IMDG Code Packaging Groups for dangerous/harmful substances reported during surveys of minor chemical incidents.

Dates and references	Primary aims	Methods of approach
1973-1977		
Dixon & Cooke, (1976; 1977).	To generate systematic data showing quantitatively and qualitatively the nature and scope of the marine litter problem.	Pilot studies in a 4.8 km study area developing appropriate beach survey techniques and analytical methods. Variables examined including shore retention rates, persistence in adjacent waters, geographical origins and sampling techniques. Measurement scales defined, applied and reviewed for containers.
1978-1983		
Unpublished results.	To provide further information on the movements and fates of plastic containers in the surface waters around the British Isles.	2,180 sealed PVC bottles released at varying distances from land in 6 experiments carried out between 1979 and 1981.
Dixon & Dixon, (1983a).	To estimate the composition and densities of surface floating litter in the North Sea.	Open-water sighting survey completed over a 4 year interval in representative areas of the North Sea utilising a strip transect survey design.

Table A6.1: Chronology for the main stages completed in the Marine Litter Research Programme. (modified from Ribic *et al.*, 1992).

Dates and references	Primary aims	Methods of approach
Dixon & Hawksley, (1980).	To determine the major trends in the composition, origins, distributions and lifetimes of litter observed on the beaches of the British Isles.	Questionnaire-based national survey carried out over a 17 month interval by 797 volunteers in all parts of the United Kingdom. Comparisons of returns with the results of previous studies with particular reference to container attributes.
Dixon & Dixon, (1980; 1981b; 1983b).	To develop standardised methods for the assessment of vessel-source marine litter from beach surveys on the shores of North-West Europe.	Large scale beach litter surveys organised in 3 study areas at 130 sample sites on the shores of the English Channel, North Sea and North Atlantic Ocean.
1981-1997		
Ribic *et al.*, (1992).	To define a set of standardised designs and methodologies for global assessments of marine litter.	Review of different sampling designs used to measure marine litter in a framework useful to others in planning and carrying out surveys in the open sea and on beaches.
Dixon, (1995).	To assess any significant changes in the amounts and composition of vessel-source marine litter following the strengthening of discharge controls applying to vessels operating in the waters around the British Isles.	Comparisons of paired "before" and "after" observations of marine litter attributes from samples collected on 185 sampling units in 7 study areas situated on the shores of the British Isles.

Table A6.1 continued.

Product	Production centre	Date of introduction of product in plastics containers	Average share in homemarket since introduction (%)	Average annual production last decade (10^6)
Ajax All Purpose Cleaner[a]	Belgium	1965	23.0	6.7
	Denmark	1968	50.0	10.2
	France	1965	40.0	20.2
	Greece	1965	80.0	4.8
	Portugal	du	du	du
	United Kingdom	1965	15.0	17.5
	USA	1963	18.0	du
	Venezuela	1964	1.8	11.7
	West Germany	1963	21.5	11.6
Harpic Lavatory Cleanser[b]	Belgium	1965	30.2	1-2
	Denmark	1958	45.0	0.8
	France	1962	du	7.9
	Greece	1960	90.0	1.5
	Kenya	1969	70.0	0.1
	Portugal	1968	95.0	0.6
	Singapore	1969	du	du
	South Africa	1963	80.0	0.8
	United Kingdom	1962	du	du

[a] Manufactured by Colgate-Palmolive Ltd. Containers fabricated from high density polyethylene, transparent or opaque, with screw closures. Paper labels front and/or reverse sides. Global production and marketing. Mould specifications and/or country of origin usually embossed on reverse side of base. Tornado logo frequently present on front side.

[b] Manufactured by Reckitt & Colman Ltd. Containers fabricated from high density polyethylene with a variety of closures. Country of origin usually overprinted with mould specifications embossed on base. Global production and marketing with large export sales from France and United Kingdom.

du Data unavailable

Table A6.2: Marketing specifications and descriptions of container samples utilised to deduce persistence in the marine environment (Cherbourg Peninsula, Channel Islands and West Jutland, 1978-79). (From: Dixon & Dixon, 1980).

Product	Production centre	Date of introduction of product in plastics containers	Average share in homemarket since introduction (%)	Average annual production last decade (10^6)
Domestos Lavatory Cleanser[a]	United Kingdom	1964	35	25.4
Dot Lavatory Cleanser[b]	United Kingdom	1963	market leader	market leader
Sanilav Lavatory Cleanser[c]	United Kingdom	1963	market leader	5.5
Parozone Lavatory Cleanser[d]	United Kingdom	1962	market leader	20.0

a Manufactured by Lever Bros. Ltd in the United Kingdom and West Germany. Containers fabricated from high density polyethylene, usually dark blue in colour. Screw aluminium enclosures usually coloured red. Paper label. Mould specifications embossed on base with individual date code. Bottles re-usable between 1964 and 1967

b Manufactured by Lever Bros. Ltd. in United Kingdom. Containers fabricated white high density polyethylene with conspicuous fluted sides. Overprinted in red and blue. Blue sprinkle closure. Mould specifications embossed on base with date code. Artwork code on sides. Hometrade product exported all markets with exception of Europe, North and South America and Australia.

c Manufactured by Jeyes Ltd. with global marketing and production. Containers fabricated high density polyethylene with varying shapes and sizes. Variety of closures. Country of origin overprinted or embossed on base with mould specifications.

d Manufactured by Jeyes Ltd with global marketing and production. Containers fabricated high density polyethylene with varying shapes and sizes. Closures usually screw cap. Country of origin overprinted or embossed on base with mould specifications.

Table A6.2 continued

SAMPLE 1 : AJAX ALL PURPOSE HOUSEHOLD CLEANER										
Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
BENELUX	510	246	78	34	1967-71	Marketed Belgium and Holland	0	5	-	-
	525	247	85	37	1972+cpt		11	36	-	-
	1020	310	110	88	1968-71		0	7	-	-
	525	247	85	37	1973+cpt		8	21	-	-
	1100	305	124	80	1972+cpt		80	29	-	-
DENMARK	880	249	102	55	1963-70	Blue screw closure	1		-	-
	490	223	88	39	1970+cpt		19	13	-	-
	880	261	97	52	1970-71		1	7	-	-
	880	261	97	52	1970+cpt		74	48	-	-
	1275	299	126	78	1970+cpt		65	44	-	-
	1275	295	125	78	1972-78		13	21	-	-
	1880	311	147	105	1970-75		20	17	-	-

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3: Descriptions, sample sizes and ages of container samples utilised to deduce persistence in the marine environment (Cherbourg Peninsula, Channel Islands and West Jutland, 1978-79). (From: Dixon & Dixon, 1980).

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
DENMARK	1880	311	147	94	1976-77	Polystyrene closure	26	9	-	-
	1880	311	147	94	1977+cpt	Polypropylene closure	18	15	-	-
	335	201	72	25	1976-78	Lavatory cleanser	1	14	-	-
	770	262	75	40	1971-77	Lavatory cleanser	9	20	-	-
FRANCE	485	224	83	35	1965-77	-	0	28	-	-
	485	224	83	35	1977+cpt	Without logo	2	36	-	-
	810	270	99	55	1965-77	-	0	19	-	-
	810	270	99	55	1977+cpt	Without logo	11	4	-	-
	1330	309	128	75	1965-78	-	0	15	-	-
	1330	309	128	75	1978+cpt	Without logo	6	7	-	-

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
GREECE	400+	204	82	34	1970-74	Ribbed upper portion	3	0	-	-
	400+	204	82	34	1976-79	Green screw closure	13	11	-	-
PORTUGAL	700+	265	78	42	1972+cpt	Oval shape	3	0	-	-
UNITED KINGDOM	332	230	73	30	1965-72	Oval with metal closure	1	0	0-1=50	0-1=21
	460	330	82	36	1965-72		1	4	1-2=41	1-2=59
	760	254	95	52	1965-72		2	0	2-3=14	2-3=30
	332	230	73	30	1972+cpt	Oval with polypropylene closure	11	8	3-4=4	3-4=12
	460	220	82	36	1972-76		7	38	4-5=5	4-5=16
	760	254	95	52	1972-76		3	23	5-6=1	5-6=3
	460	220	82	36	1976+cpt	Rectangular base polypropylene closure	25	29	6-7=1	6-7=1
	760	254	96	52	1976+cpt		69	43	7-8=1	8-9=2
									8-9=1	9-10=1

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
USA	790	254	101	49	1967-77	Ribbed upper portion	4	3	-	-
VENEZUELA	800	258	101	50	1976+cpt	Ribbed upper portion	0	1	-	-
WEST GERMANY	575	245	70	36	1963-78	*2000 variety*	15	29	0-1=21	0-1=7
	860	275	80	48	1964-76	*2000 variety*	7	4	1-2=20	1-2=12
	960	275	80	48	1977+cpt	*2002 variety*	36	3	2-3=9	2-3=5
	2240	338	152	125	1977+cpt	*2002 variety*	8	0	3-4=2	3-4=7
									6-7=4	4-5=4
									8-9=1	5-6=1
									Undated	
									=9	

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

SAMPLE 2 : HARPIC LAVATORY CLEANSER										
Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
BENELUX	445+	222[x]	62	40[x]	1971-78	Originating Holland	25	19	-	-
	445+	222[x]	62	40[x]	1971-78	Originating Belgium	9	8	-	-
DENMARK	450+ g	215[x]	65	36[x]	1971-79	Brand name *"Hardol"*	0	11	-	-
	500+ g	249	68	60[x]	1975+cpt	Scandinavian	0	2	-	-
	750+	249	77	56[x]	1971-79	market	-	-	-	-
GREECE	314+	210	55	23	1974+cpt	Oval with tapering	1	4	-	-
	595+	260	60	34	1974+cpt	sides	3	7	-	-

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
PORTUGAL	400+ g	220	60	34	1972+cpt	*Fortissimo* variety	8	0	-	-
	700+ g	265	78	42	1972+cpt	*Superactivado* variety	0	4	-	-
SINGAPORE	338	183	53	19	1972+cpt	Cylindrical	0	2	-	-
	585	209	65	30	1972+cpt		5	8	-	-
SOUTH AFRICA	330	186	54	28	1963-68	Cylindrical	1	0	-	-
	556	207	54	26	1968-72	Flat back pack	3	0	-	-
	647	267	82	53	1974-78	Oval, tapering sides	0	12	-	-
	647	287	78	55	1978+cpt	*"New Power Formula"*	4	0	-	-

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
SPAIN	700+	250	73	43	1974+cpt	Oval, tapering sides	7	4	-	-
UNITED KINGDOM	338	183	53	19	1962-70	Hometrade	3	4	0-1=36	0-1=24
	338	183	53	19	1972+cpt	General export wide orifice	11	14	1-2=133 2-3=50	1-2=73 2-3=14
	585	209	65	30	1962-70	Hometrade	5	6	3-4=19	3-4=6
	585	209	65	30	1972+cpt	General export wide orifice	17	3	4-5=14	4-5=4
									5-6=23	5-6=5
	400	215	55	23	1970-75	Curved sided puffer pack	16	2	6-7=9	6-7=2
	620	254	62	34	1970-75		23	14	7-8=4	7-8=6
	458	207	60	26	1975+cpt	Cylindrical, flip cap	63	36	8-9=3	8-9=3
	693	244	70	37	1975+cpt		161	65	9-10=1	9-10=4
									10-11=3	10-11=1
									11-12=1	11-12=2
									12-13=2	
									13-14=1	

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

SAMPLE 3 : DOMESTOS LAVATORY CLEANSER										
Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
UNITED KINGDOM	690	237	74.5	41 and 47	1964-71	Vertical ribbing on upper section	7	16	0-1=39	0-1=25
									1-2=45	1-2=48
	1140	283	82.5	52.5	1964-75	Circular ribbing on lower section	29	29	2-3=19	2-3=23
									3-4=5	3-4=10
	935	261	80	42 and 46	1971-78	Circular ribbing on lower section	93	73	4-5=14	4-4=11
									5-6=23	5-6=4
	1455	305	88	64	1975+cpt	Vertical ribbing on upper section	4	17	6-7=4	6-7=5
									8-9=2	7-8=2
	737	261	80	41	1978+cpt	Vertical ribbing on upper section	8	0	9-10=3	8-9=1
									10-11=2	9-10=5

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
UNITED KINGDOM	4546	282	189	145	1971-78	Rectangular shape	7	8	13-14=1	10-11=4
	4546	279	189	145	1978+cpt		9	0		11-12=2
										12-13=1
										13-14=2
SAMPLE 4: DOT LAVATORY CLEANSER										
UNITED KINGDOM	505	208	65	25[x]	1973+cpt	Cylindrical with fluted sides	20	35	0-1=6	0-1=9
									1-2=6	1-2=18
									2-3=8	2-3=8
SAMPLE 5: SANILAV LAVATORY CLEANSER										
UNITED KINGDOM	640+ g	250	67	33	1967-71	Domestic market	6	11	-	-
	640+ g	250	67	33	1972+cpt	Industrial market	11	13	-	-
	612+ g	250	83	24	1973-74	Oval with tapering sides	2	12	-	-
	612+ g	250	83	24	1974-78		47	26	-	-
	612+ g	250	83	24	1978+cpt		9	0	-	-
	415+ g	204	65	20	1972+cpt	Marketed Finland	12	2	-	-

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
SAMPLE 6: PAROZONE LAVATORY CLEANSER										
UNITED KINGDOM	750	267	65	45	1962-67	Indian club profile	1	0	-	-
	960	280	90	50	1969	Pear shaped upper profile	3	0	-	-
	1100	280	89	44	1971-78	*'Litre pack'*	26	48	-	-
	1100	280	89	44	1978+cpt	*'New with detergent'*	18	0	-	-
SAMPLE 7: SQEZY DISHWASHING LIQUID										
UNITED KINGDOM	510	194	64	34	1970-76	Low density polyethylene	11	8	0-1=16	0-1=15
	510	194	64	26	1976+cpt	High density polyethylene	35	22	1-2=27	1-2=31
	700	241	66	46	1970-76	Low density polyethylene	4	15	2-3=18	2-3=9
	700	241	66	32	1976+cpt	High density polyethylene	27	24	3-4=11 4-5=4	3-4=5 4-5=8
									5-6=1	5-6=1

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Country[a] of origin	Capacity (ml)[b]	Height (mm)[c]	Base dimension (mm)[d]	Empty weight (g)[e]	Man. period[f]	Comments	Sample size[g]	Sample size[h]	Age class freq. (yr)[j]	Age class freq. (yr)[k]
SAMPLE 8 : SUNLIGHT LEMON LIQUID DISHWASHING LIQUID										
UNITED KINGDOM	510	194	64	34	1970-76	Low density polyethylene	10	6	0-1=17	0-1=17
	510	194	64	26	1976+cpt	High density polyethylene	14	19	1-2=28	1-2=36
	700	241	66	46	1970-76	Low density polyethylene	12	14	2-3=15	2-3=5
	700	241	66	32	1976+cpt	High density polyethylene	46	34	3-4=13	3-4=6
									4-5=6	4-5=7
									6-7=2	5-6=2
									7-8=1	-
SAMPLE 9: CONTREXVILLE NON-CARBONATED MINERAL WATER										
FRANCE	1500	322	70	48	1976-78	Circular ribbing	21	86	-	-

a Or geographical area.

b Brimful capacity; + filling capacity.

c Height without cap; x with cap.

d Base dimension (width of long axis or diameter).

e Empty weight without cap; x with cap.

f Manufacturing periods for different container designs; cpt+ current production types.

g West Jutland sample size (50 sampling units).

h Cherbourg Peninsula and Channel Islands sample size (50 sampling units).

j Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (West Jutland - April 1979).

k Age class frequencies (yr) of container samples with individual date codes showing month and/or year of manufacture (Cherbourg Peninsula and Channel Islands - August 1978).

Table A6.3 continued.

Date & locality	Total number of drifters released[a]	Release point of each batch (geo-coordinates) I	II	III	IV	V
2&3 April 1979 Southern North Sea	500	52.11N 01.50E	53.06N 03.13E	53.45N 04.21.1E	54.32N 06.11E	55.18N 07.56E
8 December 1979 Dover Strait	350	51.6.6N 01.22.7E	51.4.6N 01.29.2E	51.2.3N 01.33.6E	50.59.4N 01.39.8E	50.58N 01.48.5E
26 January 1980 English Channel	350	50.34N 01.38.1W	50.24.4N 01.39.3W	50.13.7N 01.41W	50.02.5N 01.40.6W	49.50.4N 01.38.6W
7 April 1980 English Channel	350	49.47N 04.21.5W	49.27N 04.29W	49.12N 04.32W	49.11N 04.34W	48.56N 04.38.5W
5 November 1980 North Sea	350	57.50N 01.03E	- -	- -	- -	- -
7 August 1981 Irish Sea	280	53.40N 03.30.5W	53.47.2N 03.48W	53.57N 04.04.5W	54.01N 04.12.5W	- -

[a] equal numbers of drifters released in each batch.

Table A6.4: Dates and release points of surface drifters in the waters around the British Isles, 1979-1981.

Original contents	Sandwich Bay, Kent, 1973-1976[a]	Cherbourg Peninsula, August 1978[b]	West Jutland, April 1979†	Portugal, April 1980[c]
Lavatory cleansers	30.4	19.5	15.7	17.2
Household cleaners	16.4	14.0	19.1	12.5
Mineral waters	9.4	9.1	5.1	1.1
Dairy products (excluding milk)	3.8	5.1	3.1	2.4
Cosmetics & toiletries	6.8	4.3	3.6	6.3
Milk	4.5	8.5	7.0	3.0
Others	22.2	26.3	27.2	34.9
Unidentified	6.5	13.4	19.4	22.6
Total	**100.0**	**100.0**	**100.0**	**100.0**
Sample number (n)	**1,134**	**1,378**	**1,259**	**367**

[a] From: Dixon & Cooke (1977).

[b] From: Dixon & Dixon (1980).

[c] From: Dixon & Dixon (1983b).

Table A6.5: A summary of original contents of plastics container samples collected on West European beaches from 1973 to 1980 (percentage of sample).

Area of origin	Sandwich Bay, Kent 1973-1976 [a]	Cherbourg Peninsula, August 1978 [b]	West Jutland, April 1979 [b]	U.K. National Survey, 1978-1979 [c]	Portugal, April 1980 [d]
United Kingdom	25.0	23.9	37.6	25.9	7.9
France	21.1	22.8	7.6	6.1	4.3
Benelux	18.7	5.8	6.0	3.0	8.8
Germany [e]	11.0	5.1	6.2	2.5	5.5
Other European states	9.2	4.3	8.9	3.3	26.9
North & South America	1.6	1.9	3.6	0.9	10.8
Asia [f]	0.3	0.9	1.3	0.4	0.9
Oceania	0.3	0.7	1.2	0.2	1.5
Africa		0.4	0.6	0.1	1.2
Unidentified	12.8	34.2	27.0	57.6	32.2
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Sample number (n)	**1,134**	**2,460**	**2,849**	**8,381**	**581**

[a] Plastics containers only. From: Dixon & Dixon, (1977).

[b] From: Dixon & Dixon, (1980).

[c] From: Dixon & Hawksley, (1980).

[d] From: Dixon & Dixon, (1983b).

[e] Former Federal Republic of West Germany.

[f] Former Union of Soviet Socialist Republics (USSR).

Table A6.6: A summary of geographical origins of container samples collected on West European beaches from 1973 to 1980 (percentage of sample).

Age class (yr)	Sandwich Bay, Kent, 1973-1976 [a]	Cherbourg Peninsula, August 1978 [b]	West Jutland, April 1979[b]	U.K. National Survey, 1978-1979 [c]	Portugal, April 1980[d]
0-1	47.5	22.9	24.8	12.2	7.1
1-2	84.2	61.7	63.6	31.9	49.1
2-3	92.1	77.9	78.3	58.0	65.2
3-4	97.9	85.8	84.9	68.6	76.8
4-5	100.0	92.5	89.9	80.3	80.4
5-6	100.0	94.5	95.0	85.1	90.2

[a] Sample of 240 polyethylene bottles. From: Dixon & Dixon (1977).

[b] From: Dixon & Dixon (1980).

[c] From: Dixon & Hawksley (1980).

[d] From: Dixon & Dixon (1983b).

Table A6.7: A summary of the ages of container samples collected on West European beaches from 1973 to 1980 (cumulative percentages of samples).

Age class (yr)	Sandwich Bay, Kent, 1973- 1976	Cherbourg Peninsula, August 1978	West Jutland, April 1979	U.K. National Survey, 1978-1979	Portugal, April 1980
6-7	100.0	95.5	97.1	87.8	91.1
7-8	100.0	96.5	97.8	91.5	94.6
8-9	100.0	97.3	98.5	94.7	95.5
9-10	100.0	98.5	98.9	95.8	95.5
10-11	100.0	99.1	99.5	97.9	95.5
11-12	100.0	99.6	99.6	98.4	96.4
12-13	100.0	99.8	99.8	99.5	98.2
13-14	100.0	100.0	100.0	100.0	100.0
Sample number (n)	**240**	**802**	**954**	**188**	**112**

Table A6.7 continued

Date & locality	Batch number [a]	Recovery rate (%)	Time from release to recovery for first arrival (days)	Estimated velocity for first arrival (% mean wind speed)
2 & 3 April 1979, North Sea	I	74	2	26.4
	II	51	29	12.7
	III	45	33	9.7
	IV	50	32	14.7
	V	41	27	25.5
8 December 1979, Strait of Dover	I	44	9	18.6
	II [b]	14	55	12.7
	III	27	9	18.6
	IV	48	4	8.9
	V	70	4	9.8
26 January 1980, English Channel	I	85	2	8.5
	II	68	2	9.8
	III	54	4	6.4
	IV	60	4	9.2
	V	63	4	12.0

[a] Equal numbers of drifters released in each batch.

[b] Other recoveries in batch from the Shetland Islands (55days), the Orkney Islands (62 days) and Wick (63 days).

Table A6.8: A summary of results of surface drift experiments in the waters around the British Isles, 1979-1981 (unpublished data).

Date & locality	Batch number	Recovery rate (%)	Time from release to recovery for first arrival (days)	Estimated velocity for first arrival (% mean wind speed)
7 April 1980, English Channel.	I	20	12	6.9
	II [c]	13	55	5.8
	III	10	9	11.5
	IV	9	2	7.5
	V	24	1	6.7
5 November 1980, North Sea	I	48	26	8.0
7 August 1981, Irish Sea	I	58	7	2.3
	II	53	2	8.9
	III	69	7	2.7
	IV	36	6	3.5

[c] Includes first recovery from Northern Spain.

Table A6.8 continued

Materials	Study Area: Western Isles (n = 40) $\bar{x}$ [a]	SD [b]	CV [c]	Mainland Scotland (n = 23) $\bar{x}$	SD	CV	Combined Data (n = 63) $\bar{x}$	SD	CV
Plastics	103.6	107.1	103.4	23.1	37.1	160.6	74.2	96.1	129.5
Metals	29.3	58.3	199.0	8.9	10.9	122.5	21.9	47.7	217.8
Glass	26.2	63.2	241.2	22.1	35.1	159.1	24.7	54.3	219.8
Others	15.0	41.4	276.0	9.6	30.9	321.9	13.1	37.8	288.5
Totals	**174.2**	**160.0**	**91.8**	**63.6**	**89.6**	**140.9**	**133.9**	**147.8**	**110.4**

[a] Arithmetic means (g)
[b] Standard deviation (g)
[c] Coefficient of variation (%)

Table A6.9 Litter weight values from Scottish sub-sampling units: "before" sampling intervals, 1980-81 (g m^{-1} shoreline frontage). (From: Dixon, 1995).

Materials	Study Area: Western Isles (n = 40) $\bar{x}$ [a]	SD [b]	CV [c]	Mainland Scotland (n = 23) $\bar{x}$	SD	CV	Combined Data (n = 63) $\bar{x}$	SD	CV
Plastics	136.9	122.0	89.1	144.3	188.4	130.6	139.6	148.2	106.2
Metals	2.3	5.5	239.1	54.8	139.4	254.4	21.5	87.0	404.7
Glass	22.3	46.7	209.4	6.1	29.4	482.0	16.5	41.7	252.7
Others	4.5	24.8	551.1	15.0	42.5	283.3	8.3	32.5	391.6
Totals	**166.1**	**126.3**	**76.0**	**220.0**	**238.8**	**108.4**	**185.9**	**175.9**	**94.6**

[a] Arithmetic means (g)
[b] Standard deviation (g)
[c] Coefficient of variation (%)

Table A6.10: Litter weight values from Scottish sub-sampling units: "after" sampling intervals, 1989 & 1991 (g m^{-1} shoreline frontage). (From: Dixon, 1995).

Materials	Study Area		
	Western Isles (n = 40)	Mainland Scotland (n = 23)	Combined Data (n = 63)
Plastics	** 0.0771	** 0.0005	** 0.0022
Non-plastics	* 0.0090	0.7413	* 0.0665
All	**0.8140**	** **0.0047**	** **0.0902**

** significantly greater quantities

* significantly fewer quantities

Table A6.11: Probability values resulting from comparisons of paired litter weight values for different materials on Scottish sampling units (two-tailed probability values, Wilcoxon matched-pairs signed rank test). (From: Dixon, 1995).

Fabrication materials	Study Area: Western Isles (n = 40) $\bar{x}$ [a]	SD [b]	CV [c]	Mainland Scotland (n = 23) $\bar{x}$	SD	CV	Combined Data (n = 63) $\bar{x}$	SD	CV
	"before" sampling intervals								
Plastics	19.8	18.3	92.4	1.6	1.3	81.2	13.2	17.2	130.3
Non-plastics	15.6	14.1	90.4	1.5	1.2	80.0	10.4	13.1	126.0
All	**35.4**	**24.3**	**68.6**	**3.0**	**1.7**	**56.7**	**23.6**	**24.9**	**105.5**
	"after" sampling intervals								
Plastics	35.3	37.5	106.3	15.9	13.3	83.6	28.2	32.6	115.5
Non-plastics	9.3	8.9	95.7	6.0	5.4	90.0	8.1	7.9	97.5
All	**44.7**	**42.8**	**95.7**	**21.9**	**15.7**	**71.7**	**36.4**	**36.9**	**101.4**

[a] Arithmetic means (g)

[b] Standard deviation (g)

[c] Coefficient of variation (%)

Table A6.12: Summary statistics showing the mean numbers of containers located on Scottish sampling units during "before" and "after" sampling intervals. (From: Dixon, 1995).

Materials	Study Area		
	Western Isles (n = 40)	Mainland Scotland (n = 23)	Combined Data (n = 63)
Plastics	** 0.0032	** 0.0001	** 0.0000
Non-plastics	* 0.0043	** 0.0060	0.2585
All	**0.1112**	** **0.0001**	** **0.0001**

** significantly greater quantities

* significantly fewer quantities

Table A6.13: Probability values resulting from comparisons of paired container counts on Scottish sampling units for different fabrication materials (two-tailed probability values, Wilcoxon matched-pairs signed-rank test). (From: Dixon, 1995).

	Types of non-container litter	Western Isles (n=40)		Mainland Scotland (n=23)	
		"before"[a]	"after"[a]	"before"[a]	"after"[a]
1	Clothing	3	2	2	6
2	Confectionery wrappers	14	11	2	5
3	Fishing net	23	30	7	9
4	Fishing line	2	-	3	6
5	Glass fragments	8	5	6	2
6	Metal objects	11	4	8	5
7	Other plastic items	34	31	9	15
8	Paper and board	9	5	4	9
9	Petroleum hydrocarbons	13	7	4	1
10	Plastic bags and sheeting	23	23	8	14
11	Plastic carriers	2	3	1	2
12	Plastic cups	3	1	5	4
13	Rope and ties	27	29	8	19
14	Sewage related debris	3	2	2	8
15	Strapping bands	6	24	2	14
16	Wire	-	1	2	-
17	Other non-plastic materials or items	12	8	2	2

[a] Number of sub-sampling units in which particular types of non-container litter were present

Table A6.14: Frequency distribution showing the relative occurrence of non-container types of litter and petroleum hydrocarbons on Scottish sub-sampling units. (From: Dixon, 1995).

Materials, Original contents	Study Area											
	Western Isles				Mainland Scotland				Combined Data			
	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%
Plastics												
Beverages	33	4	195	14	1	3	76	23	34	4	271	15
Cosmetics/personal products	48	6	76	5	-	-	13	4	48	6	89	5
Dairy products (excluding milk)	39	5	12	1	2	5	6	2	41	5	18	1
Household cleaners	67	9	270	19	9	24	71	21	76	9	341	19
Lavatory cleansers	169	21	183	13	10	27	52	16	179	22	235	13
Milk	90	11	36	2	3	8	27	8	93	11	63	4
Petroleum products	18	2	209	15	4	11	31	9	22	3	240	13
Others	141	18	128	9	3	8	23	7	144	17	151	9
Unidentified	187	24	336	23	5	14	35	10	192	23	371	21
Totals	**792**	**100**	**1445**	**100**	**37**	**100**	**334**	**100**	**829**	**100**	**1779**	**100**
Glass												
Spirits	81	28	20	13	5	56	5	22	86	28	25	14
Wines	48	16	32	21	1	11	2	9	49	16	34	20
Others	70	24	79	53	2	22	11	48	72	24	90	52
Unidentified	94	32	19	13	1	11	5	22	95	31	24	14
Totals	**293**	**100**	**150**	**100**	**9**	**100**	**23**	**100**	**302**	**100**	**173**	**100**

[a] Number of containers found on sampling units

Table A6.15: Composition of containers located on Scottish sampling units by their original contents. (From: Dixon, 1995).

Materials, Original contents	Study Area											
	Western Isles				Mainland Scotland				Combined Data			
	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%
Paperboard												
Cigarettes	13	16	2	2	1	14	3	5	14	16	5	4
Milk	31	37	55	65	6	86	42	73	37	41	97	69
Others	20	24	19	23	-	-	7	13	20	22	26	19
Unidentified	19	23	8	10	-	-	4	7	19	11	12	9
Totals	**83**	**100**	**84**	**100**	**7**	**100**	**56**	**100**	**90**	**100**	**140**	**100**
Metals												
Beverages	30	15	49	47	3	18	6	7	33	15	55	28
Personal products	23	11	20	19	3	18	11	12	26	12	31	16
Petroleum products	49	24	8	8	8	47	52	57	57	26	60	31
Others	59	29	16	15	1	6	9	10	60	27	25	13
Unidentified	43	21	12	11	2	11	13	14	45	20	25	13
Totals	**204**	**100**	**105**	**100**	**17**	**100**	**91**	**100**	**221**	**100**	**196**	**100**
Other Materials												
Unidentified	42	100	3	100	-	-	-	-	42	100	3	100
Totals	**42**	**100**	**3**	**100**	**-**	**-**	**-**	**-**	**42**	**100**	**3**	**100**

[a] Number of containers found on sampling units

Table A6.15 continued.

Materials	Study Area											
	Western Isles (n=40)				Mainland Scotland (n=23)				Combined Data (n=63)			
	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%
Plastics												
Polyethylene terephthalate	-	-	210	15	-	-	66	20	-	-	276	16
Polyethylene	429	54	906	63	23	62	208	62	452	55	1114	63
Polyvinyl chloride	158	20	79	5	13	35	27	8	171	21	106	6
Others[b]	165	21	207	14	1	3	23	7	166	20	230	13
Unidentified	40	5	43	3	-	-	10	3	40	5	53	3
Totals	**792**	**100**	**1445**	**100**	**37**	**100**	**334**	**100**	**829**	**100**	**1779**	**100**
Glass												
Screw closures	202	69	87	58	6	67	15	65	208	69	102	59
Other closures	91	31	63	42	3	33	8	35	94	31	71	41
Totals	**293**	**100**	**150**	**100**	**9**	**100**	**23**	**100**	**302**	**100**	**173**	**100**
Paperboard												
Laminated aseptic packs	42	51	57	68	4	57	45	80	46	51	102	73
Cardboard & paperboard	25	30	18	21	3	43	5	9	28	31	23	16
Others	-	-	-	-	-	-	5	9	-	-	5	4
Unidentified	16	19	9	11	-	-	1	2	16	18	10	7
Totals	**83**	**100**	**84**	**100**	**7**	**100**	**56**	**100**	**90**	**100**	**140**	**100**

[a] Number of containers found during each sampling interval

[b] Polypropylene, polystyrene and co-extruded plastics laminates

Table A6.16: Composition of containers located on Scottish sampling units by their primary fabrication materials and methods of dispensing contents. (From: Dixon, 1995).

Materials	Study Area											
	Western Isles (n=40)				Mainland Scotland (n=23)				Combined Data (n=63)			
	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%	'before'[a]	%	'after'[a]	%
Metals												
Aerosol sprays	54	26	26	25	3	18	17	19	57	26	43	22
General line containers	65	32	13	12	2	12	4	4	67	30	17	9
Open top cans	6	3	6	6	1	6	6	7	7	3	12	6
Push/pull top cans	31	15	49	47	3	18	6	7	34	15	55	28
Others	15	7	10	10	8	47	54	59	23	10	64	33
Unidentified	33	16	1	1	-	-	4	4	33	15	5	3
Totals	**204**	**100**	**105**	**100**	**17**	**100**	**91**	**100**	**221**	**100**	**196**	**100**
Other Materials												
Wood	34	81	3	100	-	-	-	-	34	81	3	100
Rubber	6	14	-	-	-	-	-	-	6	14	-	-
Unidentified	2	5	-	-	-	-	-	-	2	5	-	-
Totals	**42**	**100**	**3**	**100**	**-**	**-**	**-**	**-**	**42**	**100**	**3**	**100**

Table A6.16 continued.

Age Class (years)	Study Area					
	Western Isles		Mainland Scotland		Combined Data[b]	
	"before" sampling interval[a]	"after" sampling interval[a]	"before" sampling interval[a]	"after" sampling interval[a]	"before" sampling interval[a]	"after" sampling interval[a]
0-1	9	2	7	12	16	14
1-2	22	12	6	21	28	33
2-3	26	25	5	20	31	45
3-4	8	17	4	8	12	25
4-5	12	12	2	3	14	15
5-6	2	2	1	1	3	3
6-7	7	2	1	2	8	4
7-8	6	1	1	-	7	1
8-9	2	3	-	-	2	3
9-10	3	1	-	1	3	2
10-11	1	1	-	-	2	1
11-12	-	-	-	-	-	-
12-13	2	2	-	-	-	2
13-14	-	-	-	-	-	-
14-15	-	1	-	-	-	1
>15	-	3	-	2	-	5
Totals	**99**	**84**	**27**	**70**	**126**	**154**

[a] Number of containers found during each sampling interval

[b] Sample attributes for combined data : Dishwashing liquids (United Kingdom) 11%; household cleaners (United Kingdom) 36%; lavatory cleansers (United Kingdom, France and Germany) 36%.

Table A6.17: Details of Scottish plastics container samples and their ages by the absolute dating method. (From: Dixon, 1995).

Country or region of origin	Study Area					
	Western Isles (n=40)		Mainland Scotland (n=23)		Combined Data (n=63)	
	"before"[a]	"after"[a]	"before"[a]	"after"[a]	"before"[a]	"after"[a]
Argentina	1	-	-	-	1	-
Australia	7	4	-	-	7	4
Belgium	17	10	-	1	17	11
Brazil	3	1	-	-	3	1
Canada	58	249	2	12	60	261
Denmark	117	123	4	24	121	147
France	36	36	1	3	37	39
Germany[b]	27	35	1	2	28	37
Greece	4	2	-	-	4	2
Italy	1	-	-	2	1	2
Japan	3	3	-	1	3	4
Kenya	2	-	-	-	2	-
Netherlands	15	12	-	-	15	12
New Zealand	6	1	-	-	6	1
Norway	23	17	-	1	23	18

[a] numbers of containers found during each sampling interval

[b] values for the "before" survey intervals relate to the former Federal Republic of Germany and subsequently unified Germany

Table A6.18: Geographical origins of plastics containers located on Scottish sampling units. (From: Dixon, 1995).

Country or region of origin	Study Area					
	Western Isles (n=40)		Mainland Scotland (n=23)		Combined Data (n=63)	
	"before"	"after"	"before"	"after"	"before"	"after"
Panama	-	1	-	-	-	1
Poland	5	4	-	-	5	4
Portugal	3	2	-	-	3	2
Republic of Ireland	6	15	1	1	7	16
Singapore	1	2	-	-	1	2
South Africa	9	1	-	-	9	1
Spain	16	40	1	5	17	45
Sweden	13	5	1	3	14	8
United Kingdom	241	291	17	184	258	475
USA	8	37	-	5	8	42
USSR - Russia [c]	5	6	-	2	5	8
Venezuela	1	-	-	-	1	-
Unidentified	164	548	9	88	173	636
Totals	**792**	**1445**	**37**	**334**	**829**	**1779**

[c] values for the "before" survey intervals relate to the former USSR and subsequently the Russian Federation

Table A6.18 continued.

Product type category	Current types of packages[a]		Obsolete Types of Packages[a]								Totals[a]	
			1-5 yr		6-10 yr		11-15 yr		>15 yr			
	'before'	'after'	'before'	'after'	'before'	'after'	'before'	'after'	'before'	'after'	'before'	'after'
Western Isles												
Household cleaners	133	71	22	14	15	9	11	9	-	1	**181**	**104**
Lavatory cleansers	188	66	27	1	17	12	7	5	-	4	**239**	**88**
Outboard oils	11	122	-	2	3	4	-	10	-	-	**14**	**138**
Other products	65	21	3	-	14	-	9	3	-	-	**91**	**24**
Totals	**397**	**280**	**52**	**17**	**49**	**25**	**27**	**27**	**-**	**5**	**525**	**354**
Mainland Scotland												
Household cleaners	4	24	1	5	-	1	-	-	-	2	**5**	**32**
Lavatory cleansers	3	16	2	3	1	1	-	3	-	1	**6**	**24**
Outboard oils	-	19	-	-	-	-	-	1	-	-	**-**	**20**
Other products	2	13	-	1	-	2	-	-	-	-	**2**	**16**
Totals	**9**	**72**	**3**	**9**	**1**	**4**	**-**	**4**	**-**	**3**	**13**	**92**

[a] Number of containers found during each sampling interval

Geographical origins of container samples: Asia & Oceania 1.4%; Canada 33.5%; Denmark 22.3%; France 3.8%; Germany 3.0%; Spain 5.8%; United Kingdom 27.7%; USA 2.5%.

Table A6.19: Details of Scottish plastics container samples and their ages by the relative dating method. (From: Dixon, 1995).